1966 Yearbook of Astronomy

Editor PATRICK MOORE

EYRE & SPOTTISWOODE

YEARBOOK OF ASTRONOMY 1966

EDITED BY
PATRICK MOORE

Eyre & Spottiswoode (Publishers) Ltd
LONDON

First published in 1965
© 1965 *by Eyre & Spottiswoode (Publishers) Ltd,*
167 *Fleet Street, London EC*4
Printed in Great Britain by
W. & J. Mackay & Co Ltd, Chatham

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Editorial

The favourable reception given to the last issue of the *Yearbook* has indicated that no fundamental changes in style or content are called for. The 1966 version follows closely on the pattern of its predecessors, with the star-charts, assortment of articles, stellar notes and current topics as before.

Once again, grateful acknowledgement must be made to Dr J. G. Porter, who has made vital contributions; virtually all of Part I is his work, excluding only the general notes at the end of each monthly section. I must also express my thanks to the team of article-writers, and to the publishers, particularly Maurice Temple-Smith.

PATRICK MOORE

INDEX TO ARTICLES IN PREVIOUS *YEARBOOKS*

BAXTER, W. M. *Observing the Sun:* 1963.
BEET, E. A. *Astronomy as a Career:* 1963.
BRINTON, HENRY. *A Run-off Observatory:* 1963.
—*Astronomy and Navigation:* 1964.
—*Measuring the Universe:* 1965.
CALVERT, H. R. *Astronomy at the Science Museum:* 1962.
CAMPBELL, D. A. *Astronomical Photography for Amateurs:* 1962.
CATTERMOLE, P. *Selonology: or Geology Applied to the Moon:* 1964.
DALL, H. E. *Eyepieces – a Practical Assessment:* 1963.
DE VAUCOULEURS, G. *Problems of Mars:* 1963.
FOX, W. E. *The Great Red Spot on Jupiter:* 1964.
GARSTANG, R. H. *The Structure of the Galaxy:* 1962.
GATLAND, K. W. *The Astronautical Outlook:* 1965.
GRIFFIN, R. *Automation in Astronomy:* 1962.
—*Variable Stars:* 1963.
HEY, M. H. *Meteorites and Life:* 1963.
HOLE, G. A. *Telescopic Faults:* 1965.
HYDE, F. W. *The Radio Sun:* 1965.
JARRETT, A. H. *Recent Rocket Research:* 1962.
JENNISON, R. C. *Radio and Radar Astronomy:* 1962.
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—*Harrison, Maskelyne and the Longitude Problem:* 1962.
MILES, H. *With Mariner II to Venus:* 1964.
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MIYAMOTO, S. *Clouds in the Atmosphere of Mars:* 1965.
MOORE, PATRICK. *The Origin of the Universe:* 1962.
—*Introduction to Mars:* 1965.

MUIRDEN, J. *A Cycle of Clusters and Nebulæ:* 1965.
MURDIN, P. *Stellar Clusters:* 1963.
PEEK, B. M. *The Satellites of Jupiter:* 1962.
PORTER, J. G. *Astronomy and Space Research:* 1963.
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RONAN, C. A. *Planetary Nebulæ:* 1964.
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WILDEY, H. *Telescope Mountings:* 1964.
WRIGHT, H. N. D. *The Surface of Saturn:* 1964.

PART ONE

Events of 1966

Monthly Charts and Astronomical Phenomena

Notes on the Star Charts

The stars, together with the Sun, Moon and planets, seem to be set on the surface of the celestial sphere, which appears to rotate about the Earth from east to west. Since it is impossible to represent a curved surface accurately on a plane, any kind of star map is bound to contain some form of distortion. But it is well known that the eye can endure some kinds of distortion better than others, and it is particularly true that the eye is most sensitive to deviations from the vertical and horizontal. For this reason the star charts given in this volume on pages 6 to 29 have been designed to give a true representation of vertical and horizontal lines, whatever may be the resulting distortion in the shape of a constellation figure. It will be found that the amount of distortion is, in general, quite small, and is only obvious in the case of large constellations such as Leo and Pegasus, when these appear at the top of the charts, and so are drawn out sideways.

The charts show all stars down to the fourth magnitude, together with a number of fainter stars which are necessary to define the shape of a constellation. There is no standard system for representing the outlines of the constellations, and triangles and other simple figures have been used to give outlines which are easy to follow with the naked eye. The names of the constellations are given, together with the proper names of the brighter stars. The apparent magnitudes of the stars are indicated roughly by using four different sizes of dots, the larger dots representing the bright stars.

There are four such charts at each opening, and these give a complete coverage of the sky up to an altitude of 62½ degrees; there are twelve such sets to cover the entire year. The upper two charts show the southern sky, south being at the centre; the coverage is 200 degrees in azimuth, from a little north of east

(top left) to a little north of west (top right). The two lower charts show the northern sky, from a little south of west (lower left) to a little south of east (lower right). There is thus an overlap east and west.

The charts have been drawn for a latitude of 52 degrees, but may be taken without appreciable error to apply to all parts of the British Isles. They will also be equally suitable for any other part of the world having a north latitude of about 52 degrees – e.g. parts of Europe and Asia, and Canada. In such cases the times given must be taken as local time, and not G.M.T., which applies only to the British Isles.

Because the sidereal day is shorter than the solar day, the stars appear to rise and set about four minutes earlier each day, which amounts to two hours in a month. Hence the twelve sets of charts are sufficient to give the appearance of the sky throughout the day at intervals of two hours, or at the same time of night at monthly intervals throughout the year. The actual range of dates and times when the stars on the charts are visible is indicated at the top of each page. This information is summarized in the following table, which gives the number of the star chart to be used for any given month and time.

G.M.T.	16^h	18^h	20^h	22^h	0^h	2^h	4^h	6^h
January	10	11	12	1	2	3	4	5
February		12	1	2	3	4	5	6
March			2	3	4	5	6	
April			3	4	5	6		
May			4	5	6	7		
June			5	6	7			
July			6	7	8	9		
August			7	8	9	10	11	
September		7	8	9	10	11	12	
October		8	9	10	11	12	1	
November	8	9	10	11	12	1	2	3
December	9	10	11	12	1	2	3	4

The charts are drawn to scale, and estimates of altitude and azimuth may be made from them. These values will necessarily be mere approximations, since no observer will be exactly on the meridian of Greenwich at 52 degrees latitude, but they will generally serve for the identification of stars and planets. The horizontal measurements, marked at every ten degrees, give the azimuths (or true bearings) measured from the north round through east (90 degrees), south (180 degrees), and west (270 degrees). The vertical measurements, similarly marked, give the altitudes of the stars up to $62\frac{1}{2}$ degrees.

The ecliptic is drawn as a broken line on which the longitude is marked at every ten degrees; the positions of the planets at any time are then easily found by reference to the table immediately following the star charts on page 32.

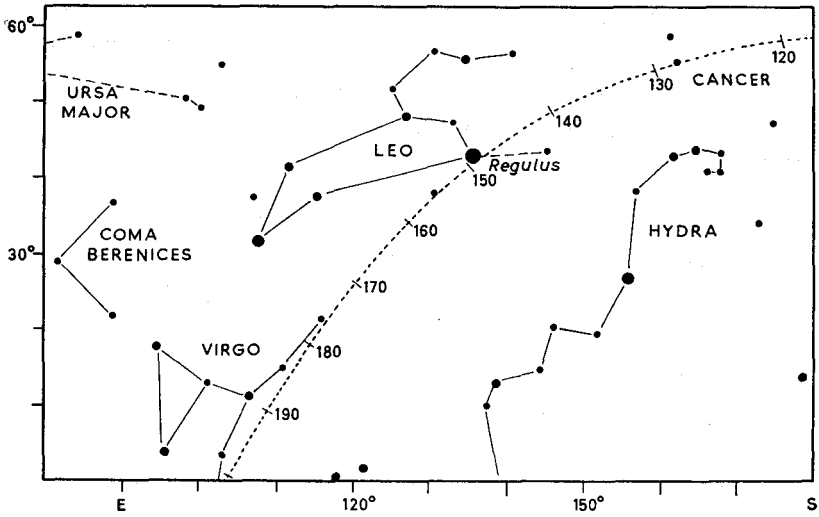
There is a curious illusion that stars at an altitude of 60 degrees or more are actually overhead, and the beginner may often feel that he is leaning over backwards in trying to see them. These high-altitude stars, being nearer the pole, move more slowly across the sky, and a different kind of map may therefore be used. These overhead stars are given separately on pages 30 and 31, the entire year being covered at one opening. Each of the four maps shows the overhead stars at times which correspond to those of three of the main star charts. The position of the zenith in latitude 52 degrees is indicated by a cross, and this cross also marks the centre of a circle which is 35 degrees from the zenith, and which therefore indicates an altitude of 55 degrees; there is thus a small overlap with the main charts.

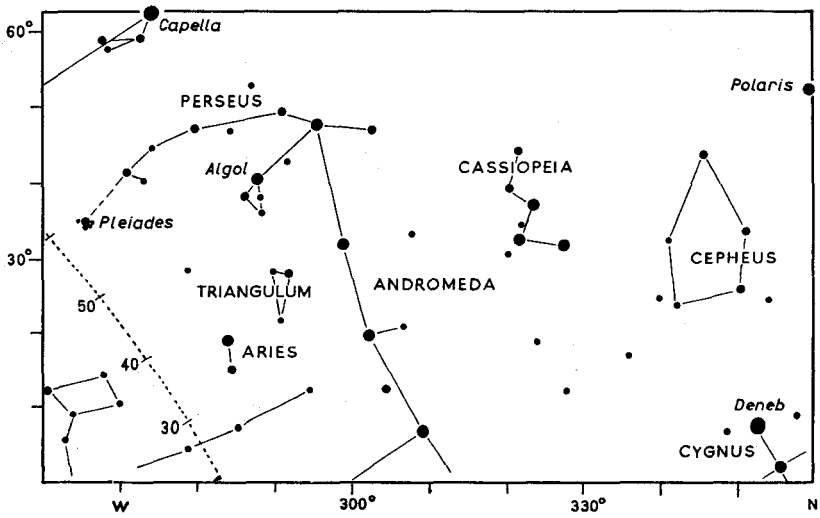
The broken line leading from north to south is numbered to indicate the corresponding main chart. Thus on page 30 the N-S line numbered 6 is to be regarded as an extension of the S line of chart 6 on pages 16 and 17, and at the top of these pages are given dates and times which are appropriate.

The scale is the same on all the charts (approximately 25 degrees to the inch), but the overhead stars are plotted as a true map on a conical projection, and are not simple graphs like the main charts.

2L

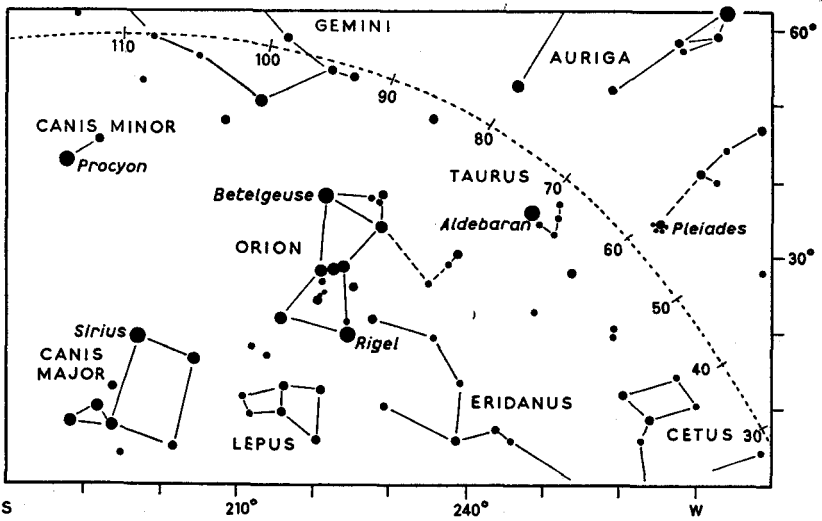
November 6 at 5h	November 21 at 4h
December 6 at 3h	December 21 at 2h
January 6 at 1h	January 21 at midnight
February 6 at 23h	February 21 at 22h
March 6 at 21h	March 21 at 20h

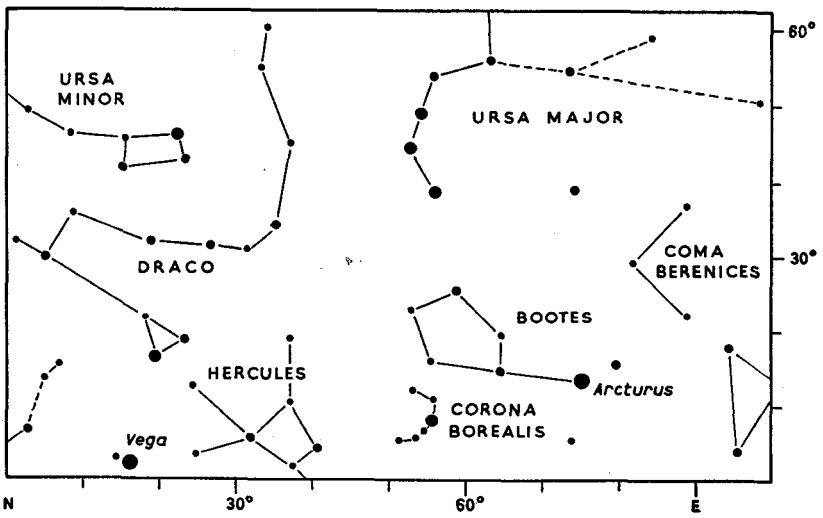




November 6 at	5h	November 21 at	4h
December 6 at	3h	December 21 at	2h
January 6 at	1h	January 21 at	midnight
February 6 at	23h	February 21 at	22h
March 6 at	21h	March 21 at	20h

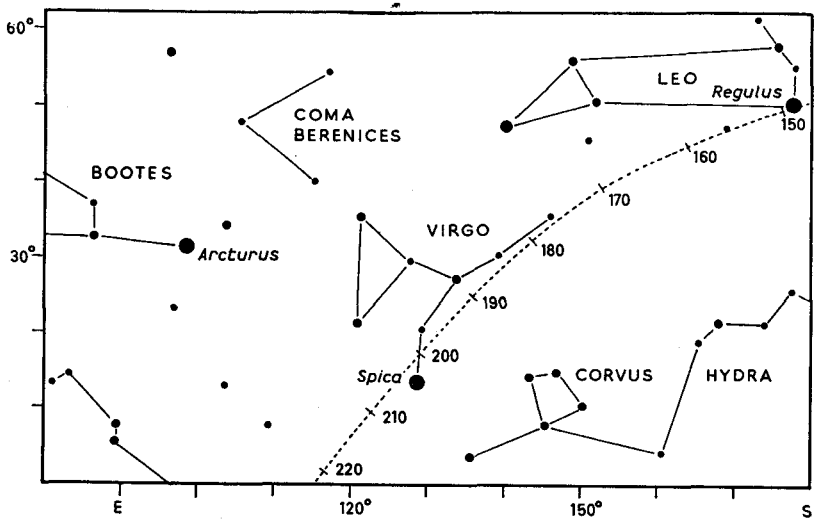
2R

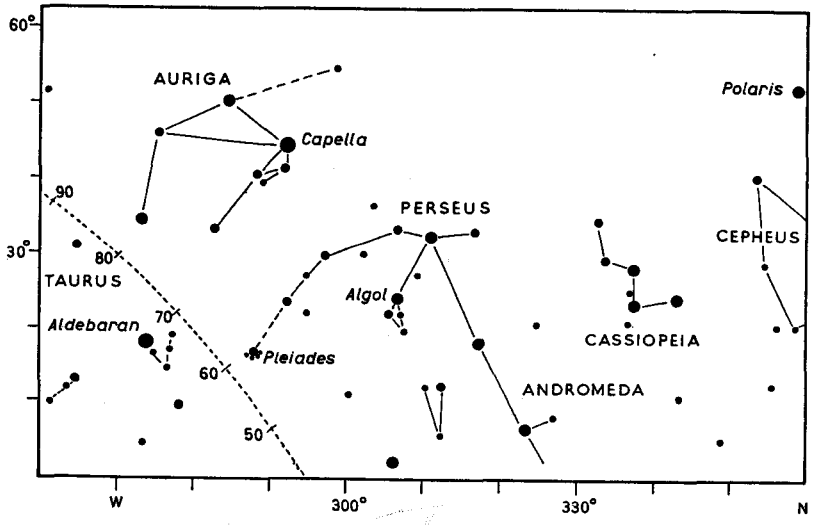




3L

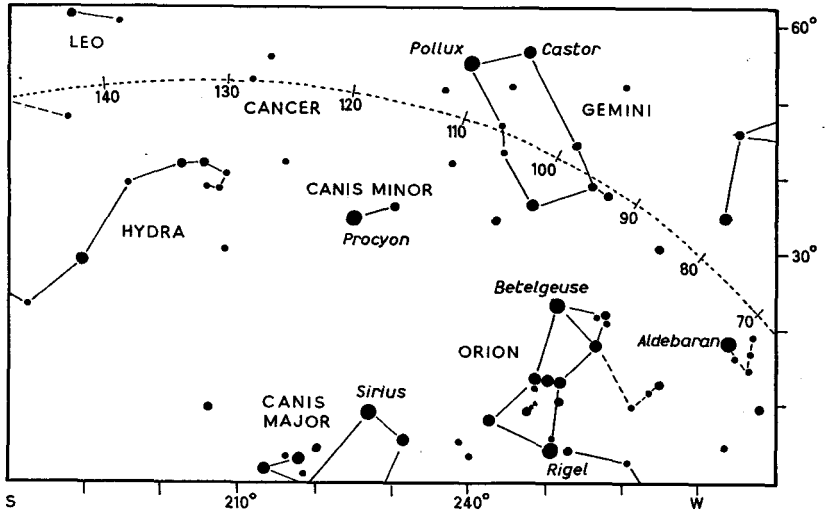
December 6 at 5h	December 21 at 4h
January 6 at 3h	January 21 at 2h
February 6 at 1h	February 21 at midnight
March 6 at 23h	March 21 at 22h
April 6 at 21h	April 21 at 20h

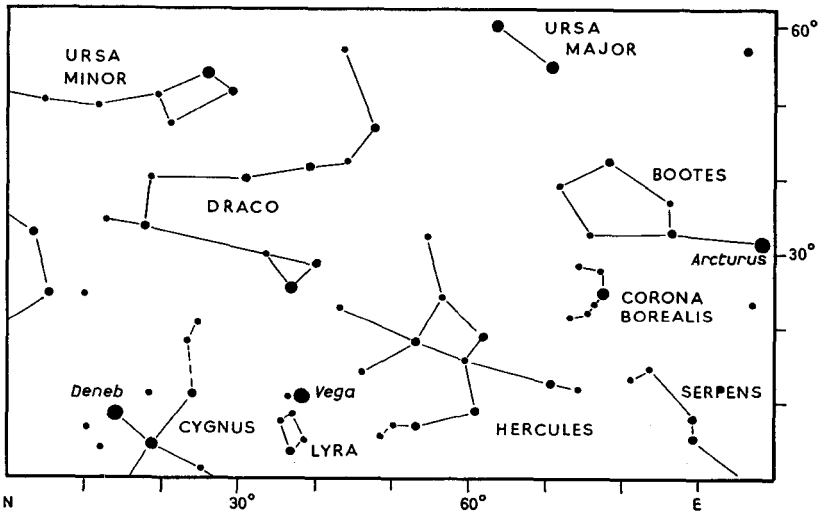




December 6 at	5h	December 21 at	4h
January 6 at	3h	January 21 at	2h
February 6 at	1h	February 21 at	midnight
March 6 at	23h	March 21 at	22h
April 6 at	21h	April 21 at	20h

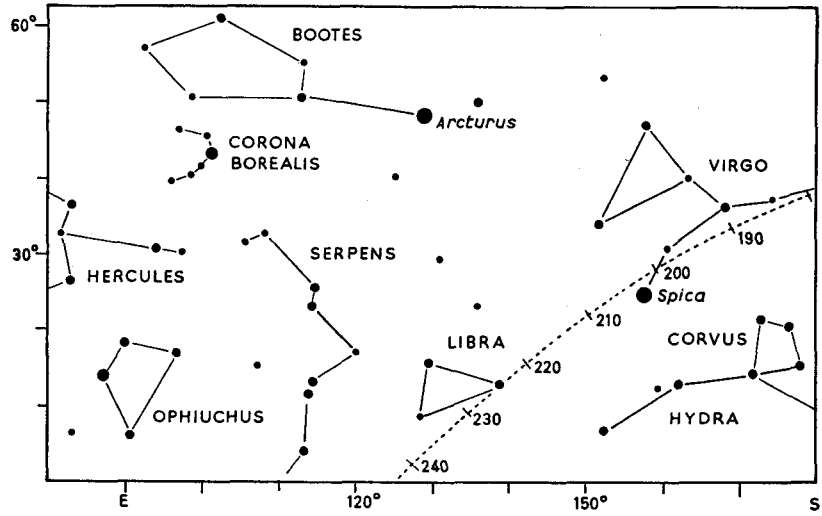
3R

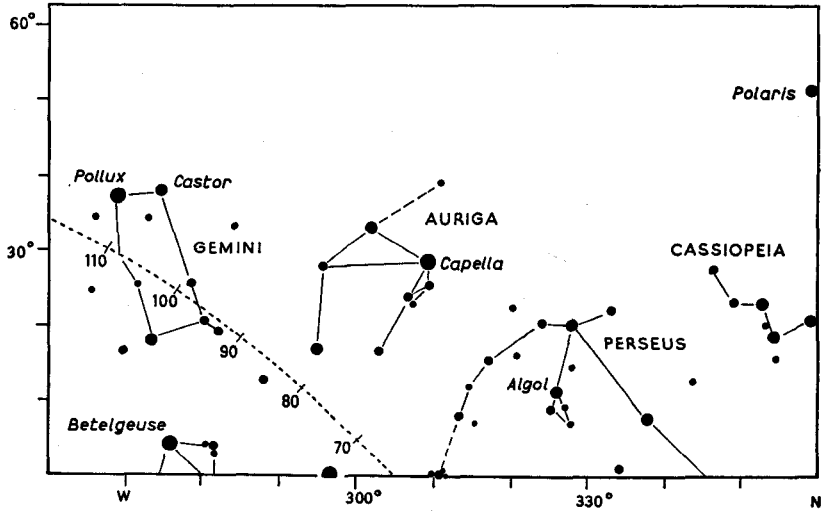




4L

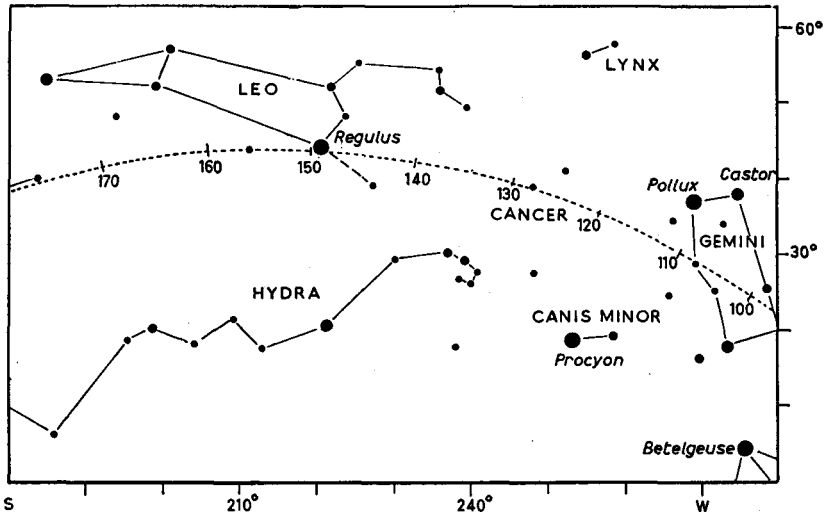
January 6 at 5h	January 21 at 4h
February 6 at 3h	February 21 at 2h
March 6 at 1h	March 21 at midnight
April 6 at 23h	April 21 at 22h
May 6 at 21h	May 21 at 20h

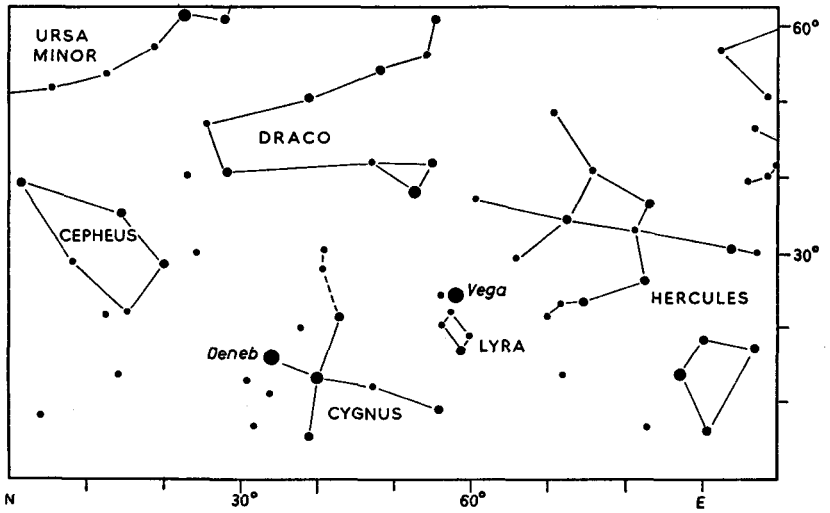




January 6 at	5^h	January 21 at	4^h
February 6 at	3^h	February 21 at	2^h
March 6 at	1^h	March 21 at	midnight
April 6 at	23^h	April 21 at	22^h
May 6 at	21^h	May 21 at	20^h

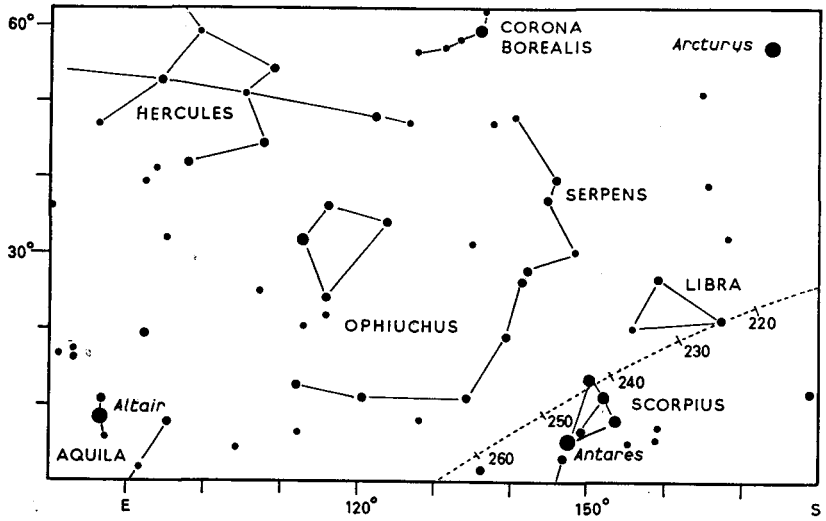
4R

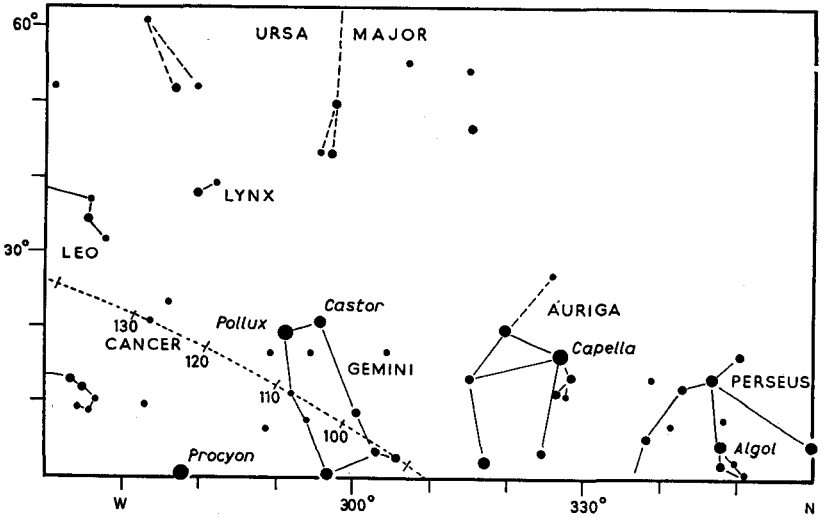




5L

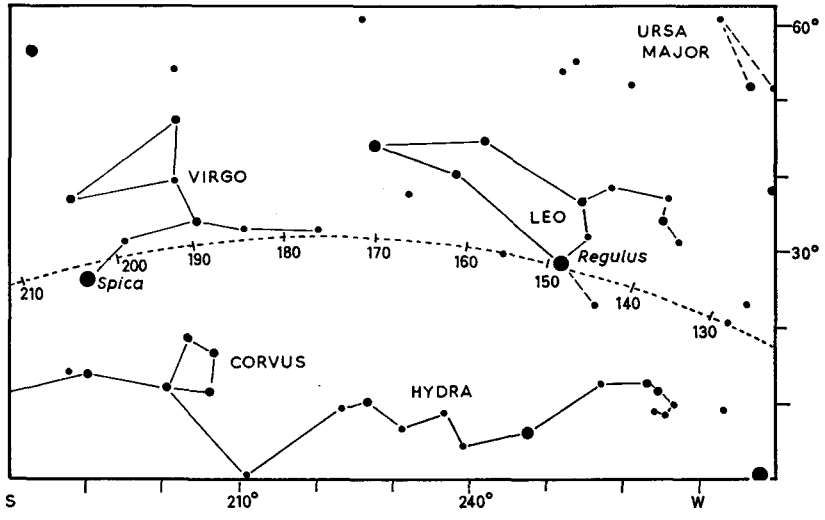
January 6 at 7^h	January 21 at 6^h
February 6 at 5^h	February 21 at 4^h
March 6 at 3^h	March 21 at 2^h
April 6 at 1^h	April 21 at midnight
May 6 at 23^h	May 21 at 22^h

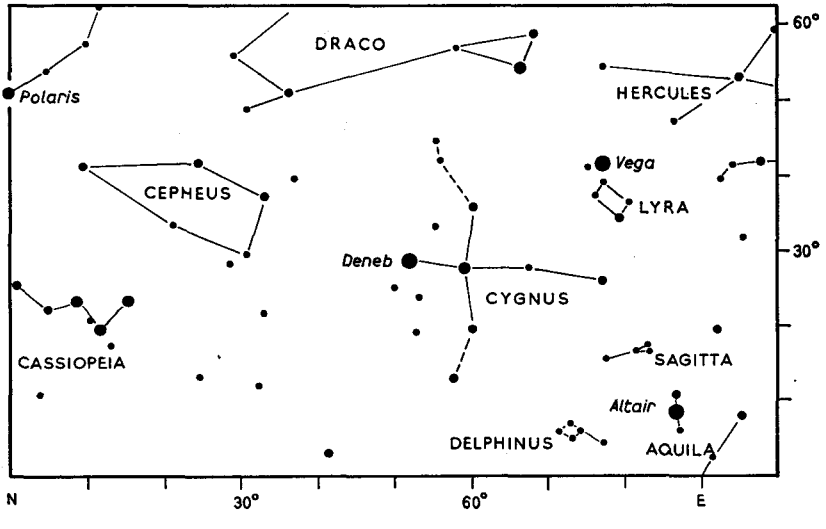




January 6 at	7h	January 21 at	6h
February 6 at	5h	February 21 at	4h
March 6 at	3h	March 21 at	2h
April 6 at	1h	April 21 at	midnight
May 6 at	23h	May 21 at	22h

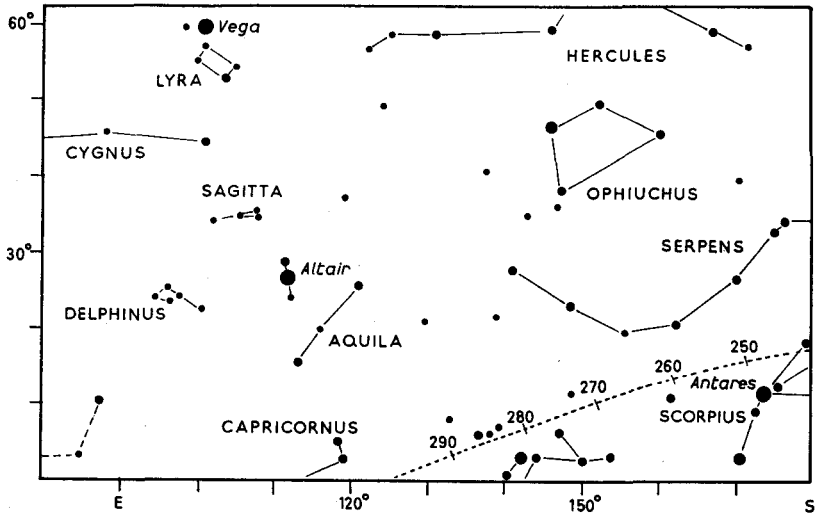
5R

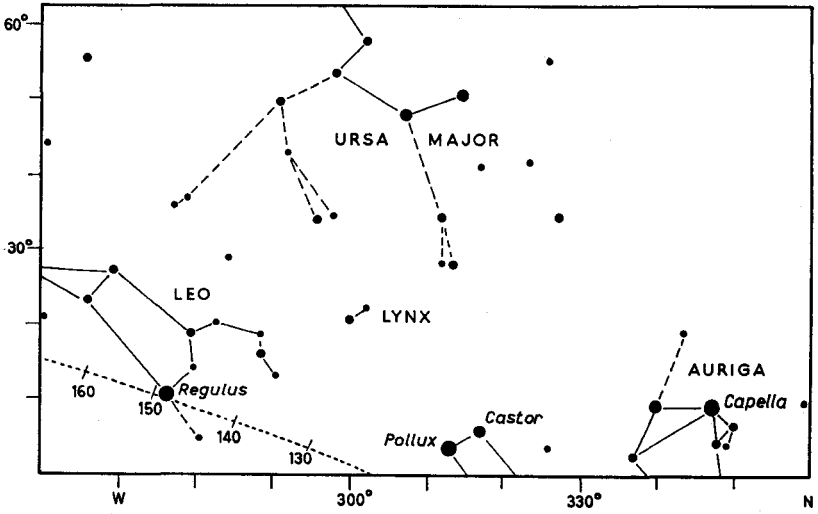




6L

March 6 at 5h	March 21 at 4h
April 6 at 3h	April 21 at 2h
May 6 at 1h	May 21 at midnight
June 6 at 23h	June 21 at 22h
July 6 at 21h	July 21 at 20h





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April 6 at	3^h	April 21 at	2^h
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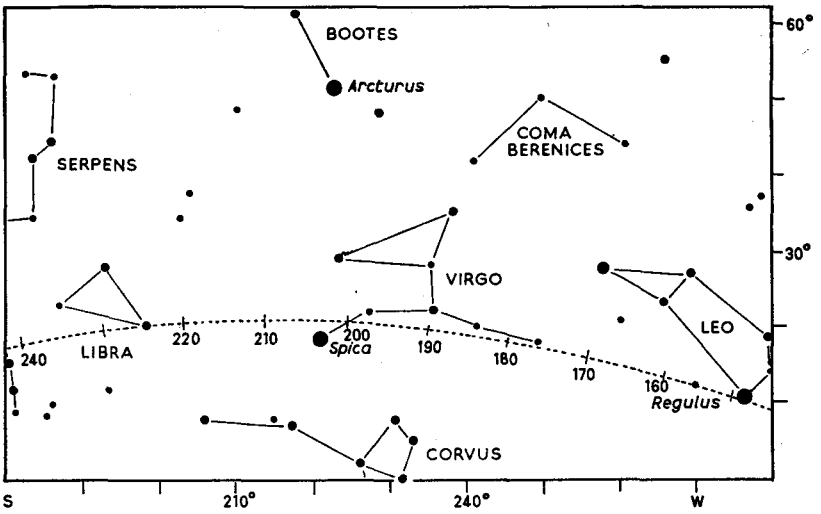
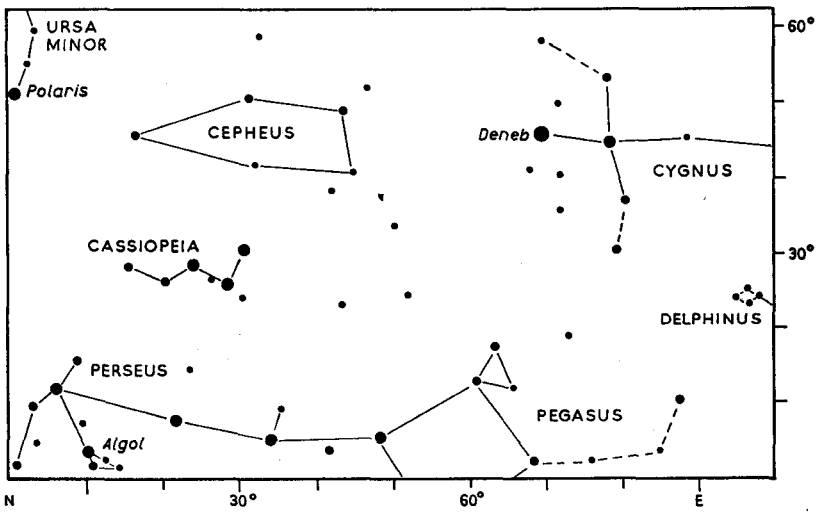
July 6 at	21^h	July 21 at	20^h

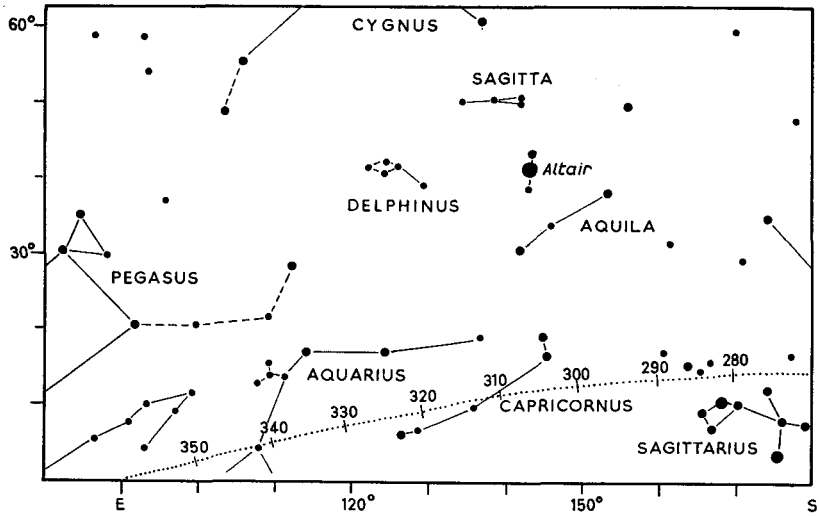
6R

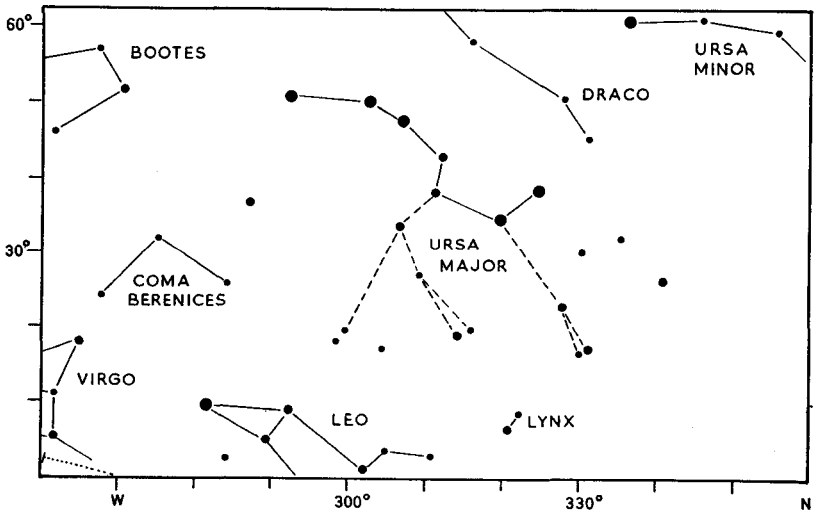




7L

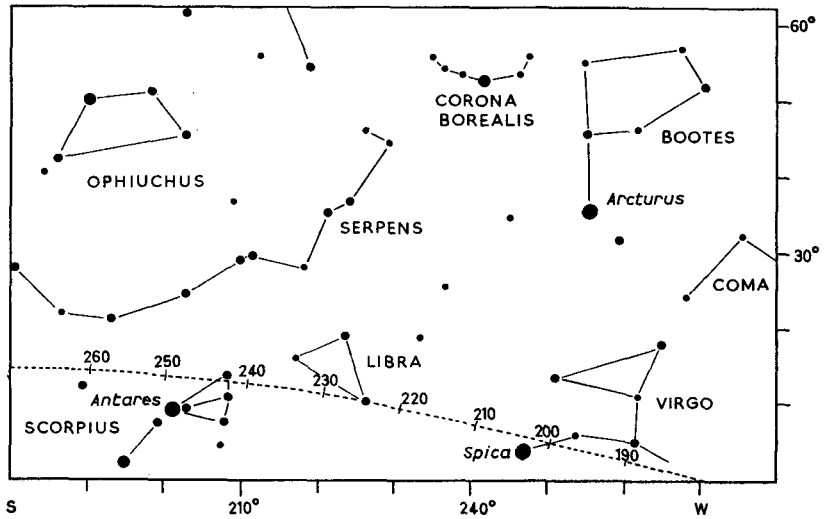
May 6 at 3h	May 21 at 2h
June 6 at 1h	June 21 at midnight
July 6 at 23h	July 21 at 22h
August 6 at 21h	August 21 at 20h
September 6 at 19h	September 21 at 18h

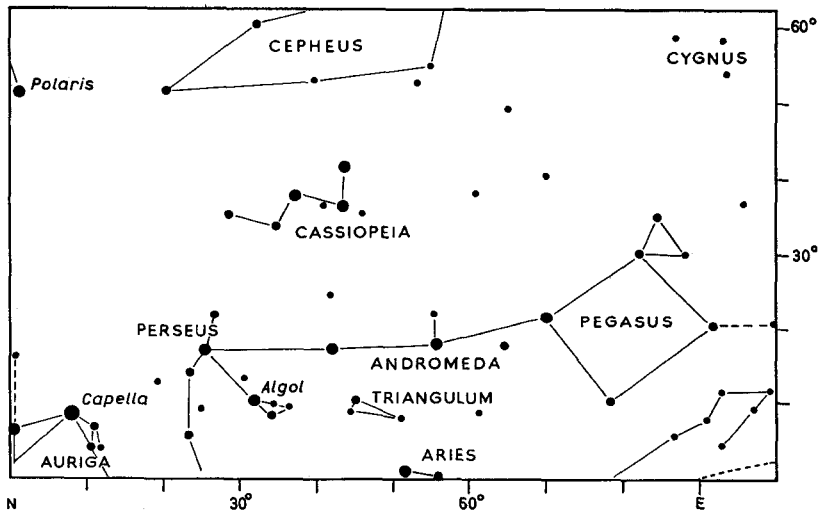




May 6 at 3h	May 21 at 2h
June 6 at 1h	June 21 at midnight
July 6 at 23h	July 21 at 22h
August 6 at 21h	August 21 at 20h
September 6 at 19h	September 21 at 18h

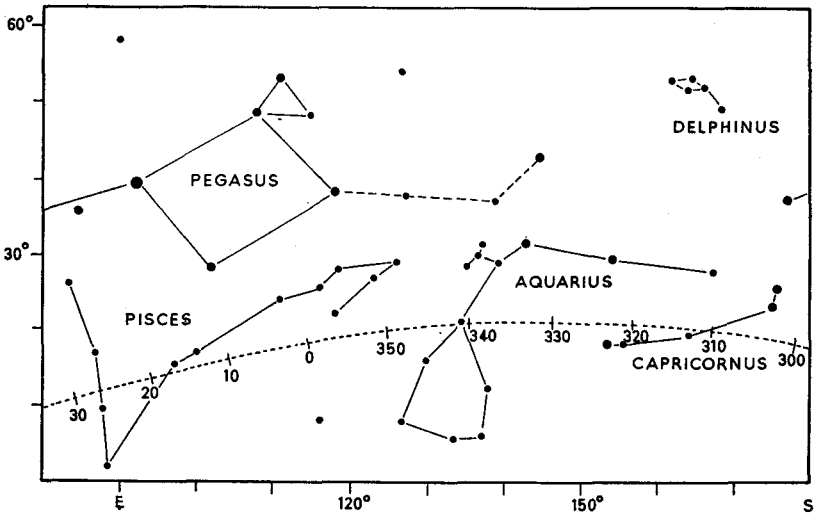
7R

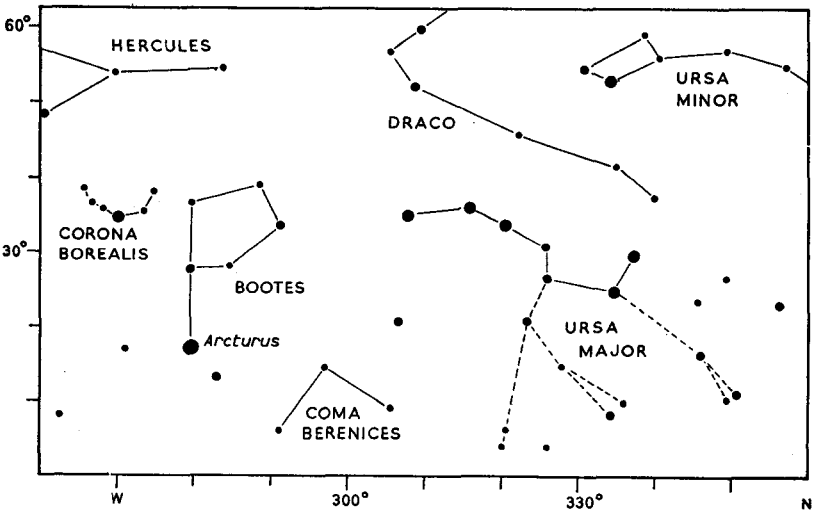




8L

July 6 at 1h	July 21 at midnight
August 6 at 23h	August 21 at 22h
September 6 at 21h	September 21 at 20h
October 6 at 19h	October 21 at 18h
November 6 at 17h	November 21 at 16h

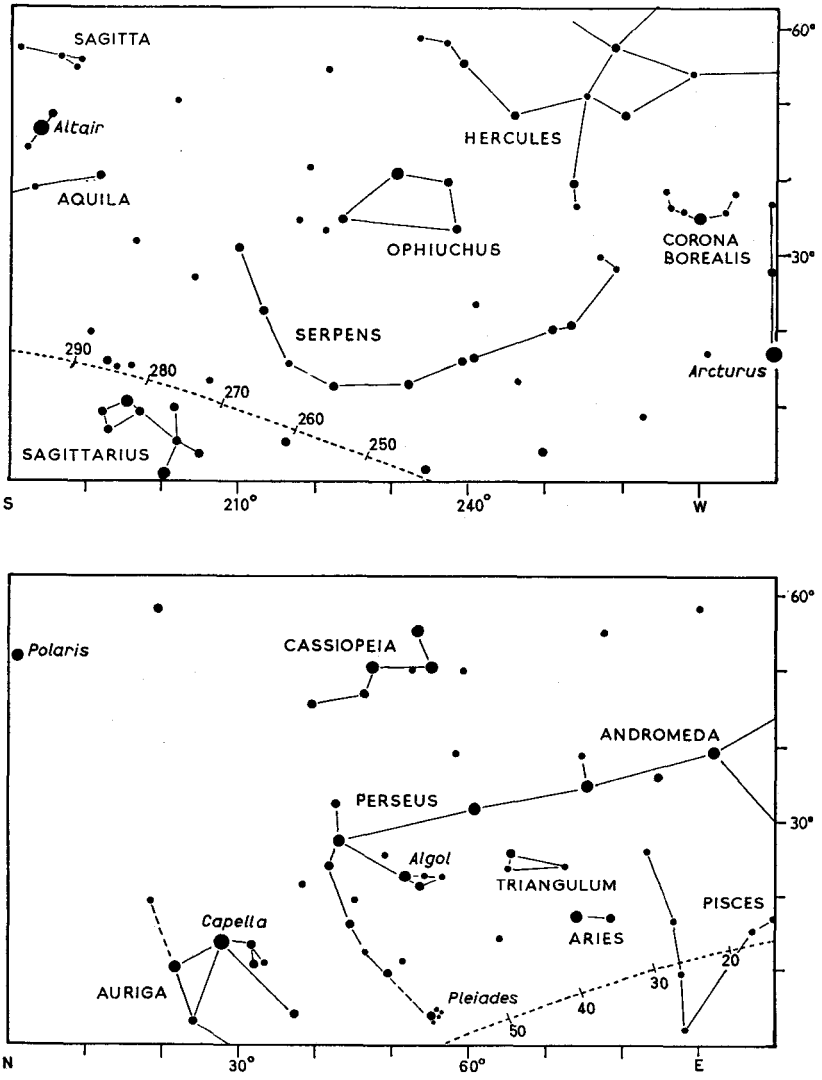




July 6 at 1h
August 6 at 23h
September 6 at 21h
October 6 at 19h
November 6 at 17h

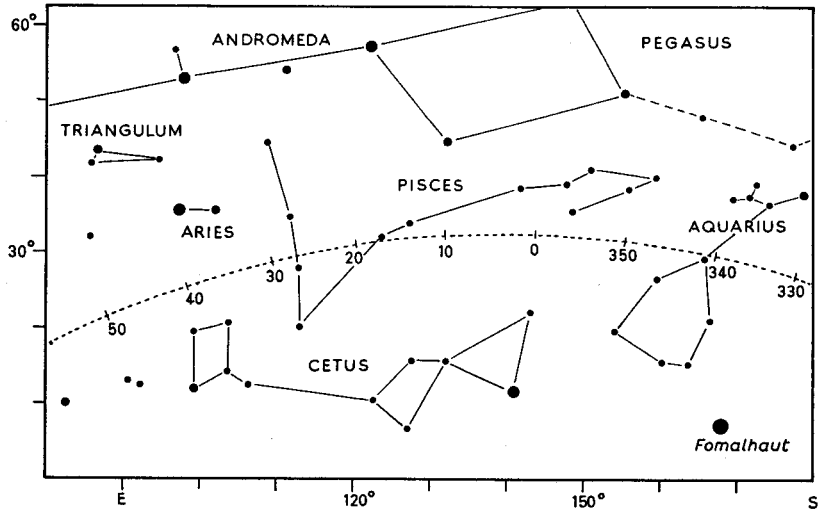
July 21 at midnight
August 21 at 22h
September 21 at 20h
October 21 at 18h
November 21 at 16h

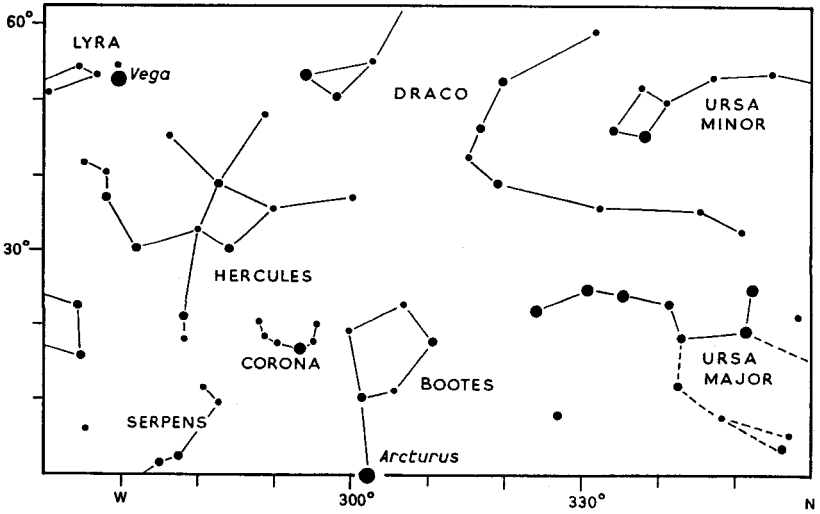
8R



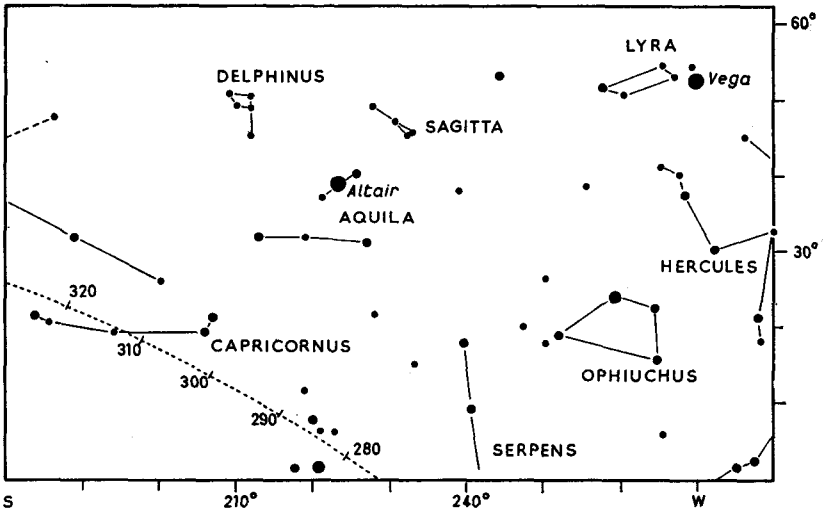
9L

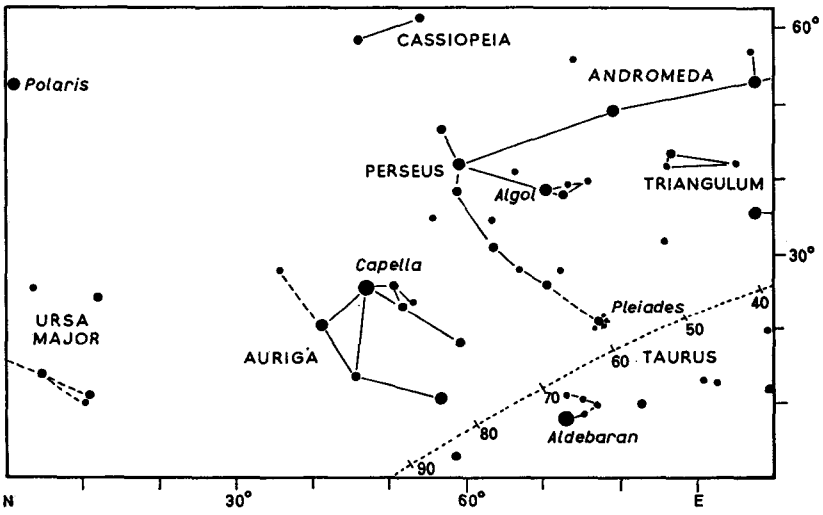
August 6 at 1h	August 21 at midnight
September 6 at 23h	September 21 at 22h
October 6 at 21h	October 21 at 20h
November 6 at 19h	November 21 at 18h
December 6 at 17h	December 21 at 16h





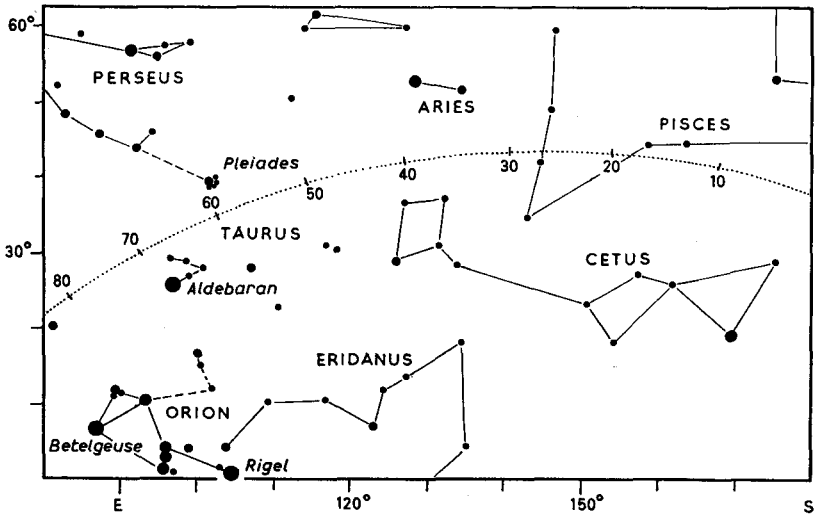
August 6 at 1h	August 21 at midnight	**9R**
September 6 at 23h	September 21 at 22h	
October 6 at 21h	October 21 at 20h	
November 6 at 19h	November 21 at 18h	
December 6 at 17h	December 21 at 16h	

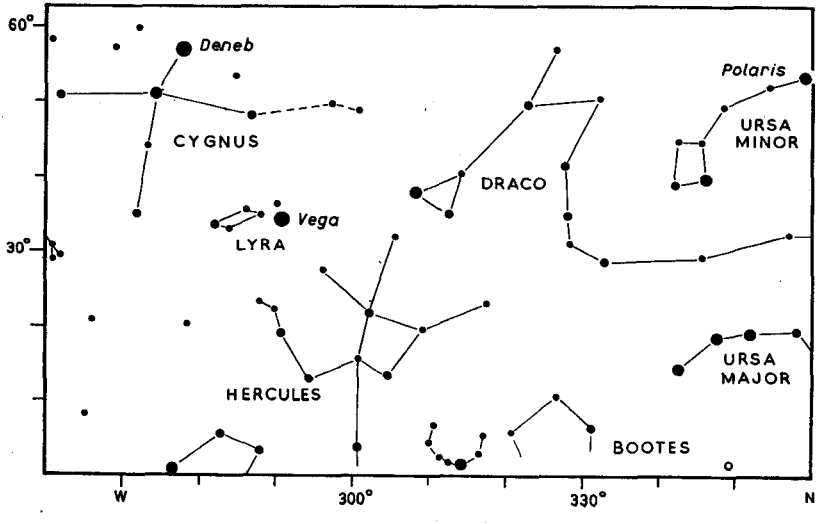




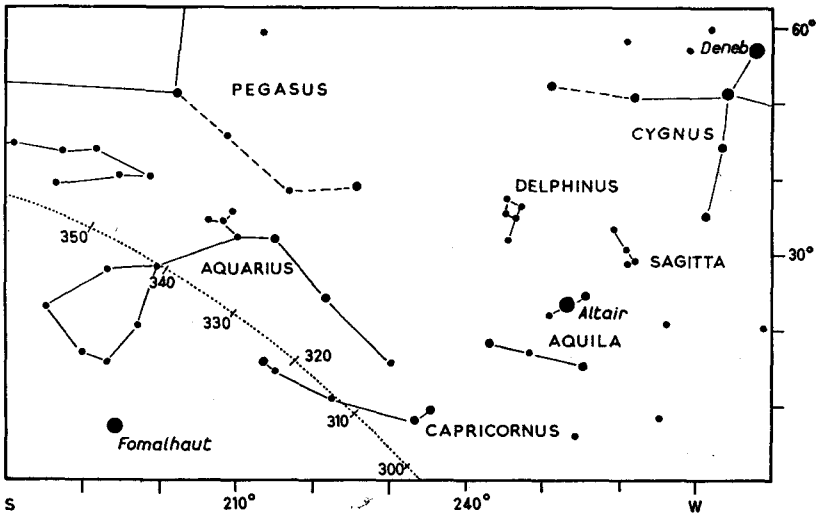
10L

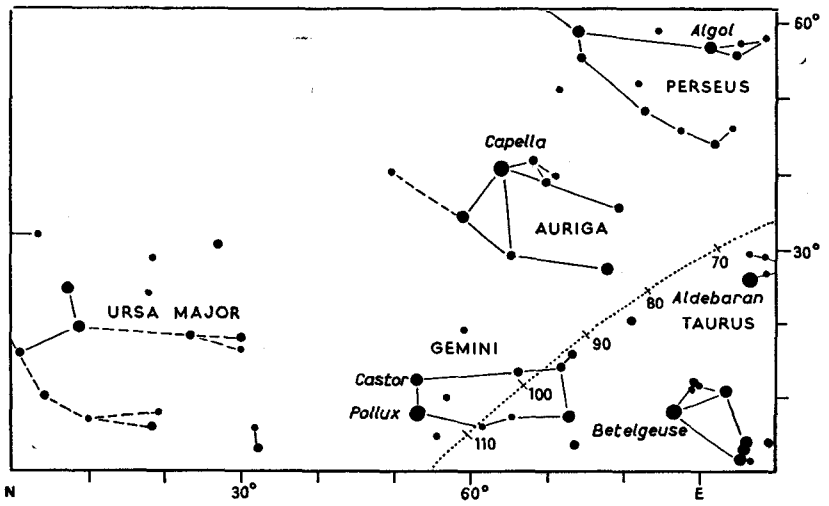
August 6 at 3h	August 21 at 2h
September 6 at 1h	September 21 at midnight
October 6 at 23h	October 21 at 22h
November 6 at 21h	November 21 at 20h
December 6 at 19h	December 21 at 18h





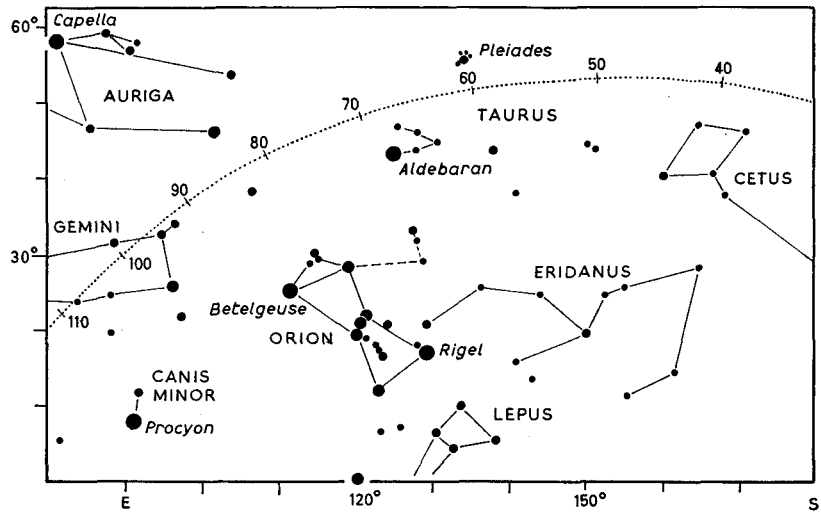
August 6 at 3h	August 21 at 2h	**10R**
September 6 at 1h	September 21 at midnight	
October 6 at 23h	October 21 at 22h	
November 6 at 21h	November 21 at 20h	
December 6 at 19h	December 21 at 18h	

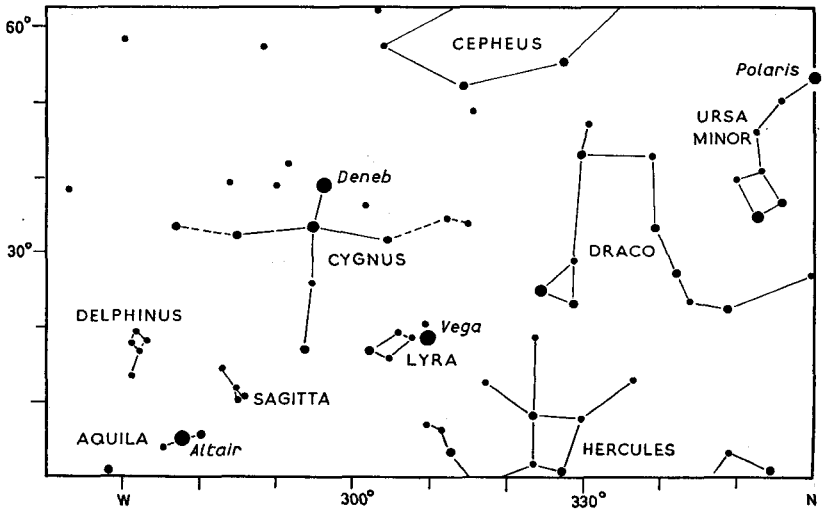




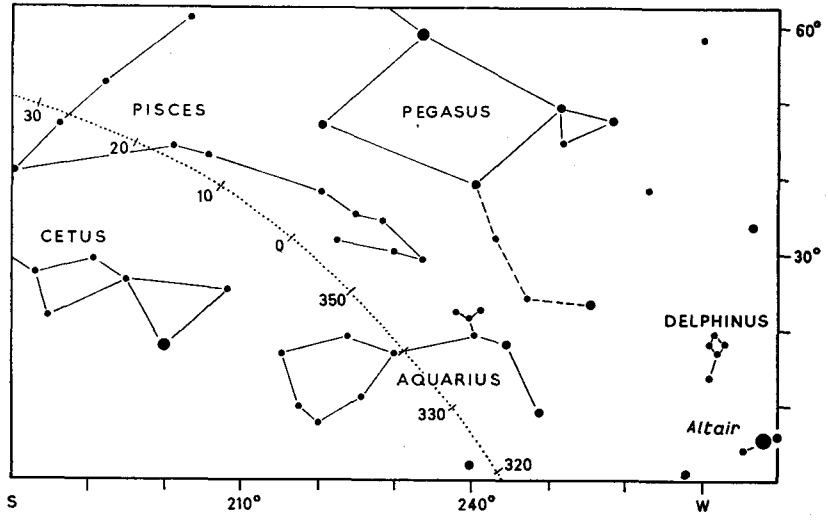
11L

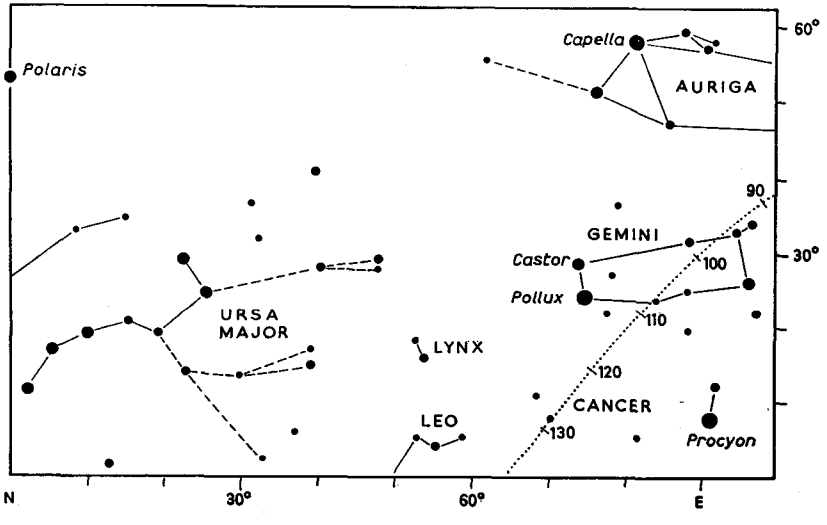
September 6 at 3h	September 21 at 2h
October 6 at 1h	October 21 at midnight
November 6 at 23h	November 21 at 22h
December 6 at 21h	December 21 at 20h
January 6 at 19h	January 21 at 18h





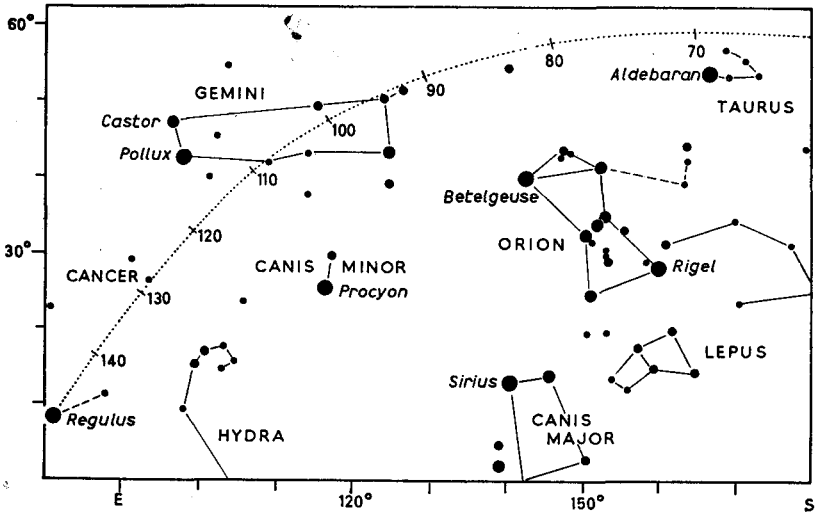
September 6 at 3h	September 21 at 2h	**11R**
October 6 at 1h	October 21 at midnight	
November 6 at 23h	November 21 at 22h	
December 6 at 21h	December 21 at 20h	
January 6 at 19h	January 21 at 18h	

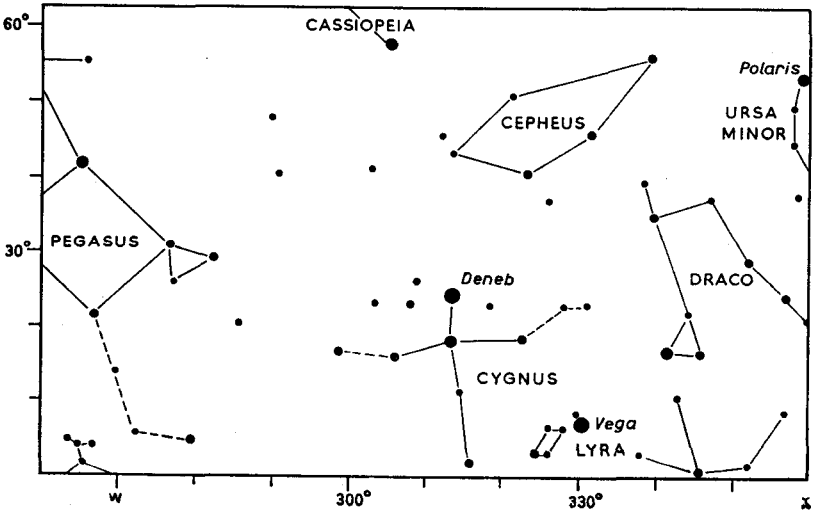




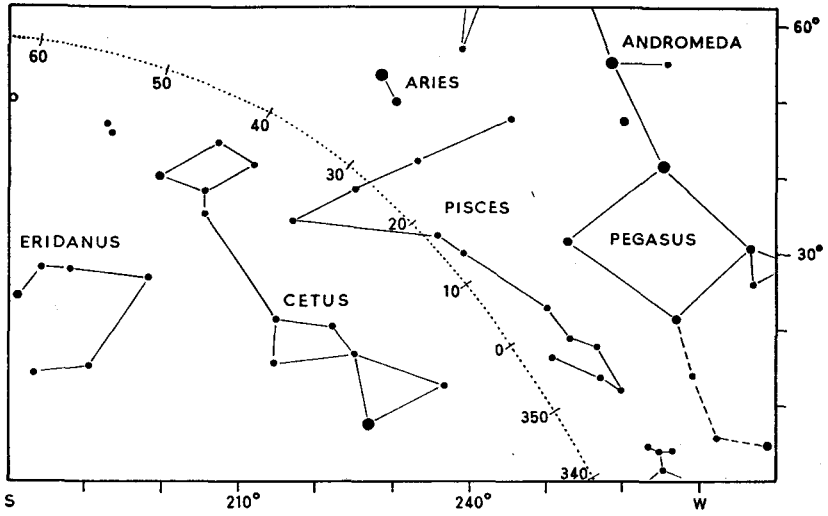
12L

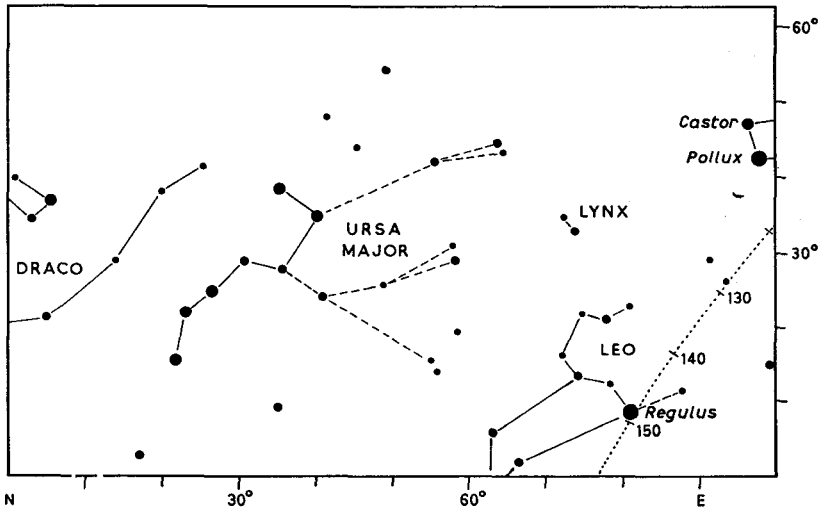
October 6 at 3h	October 21 at 2h
November 6 at 1h	November 21 at midnight
December 6 at 23h	December 21 at 22h
January 6 at 21h	January 21 at 20h
February 6 at 19h	February 21 at 18h

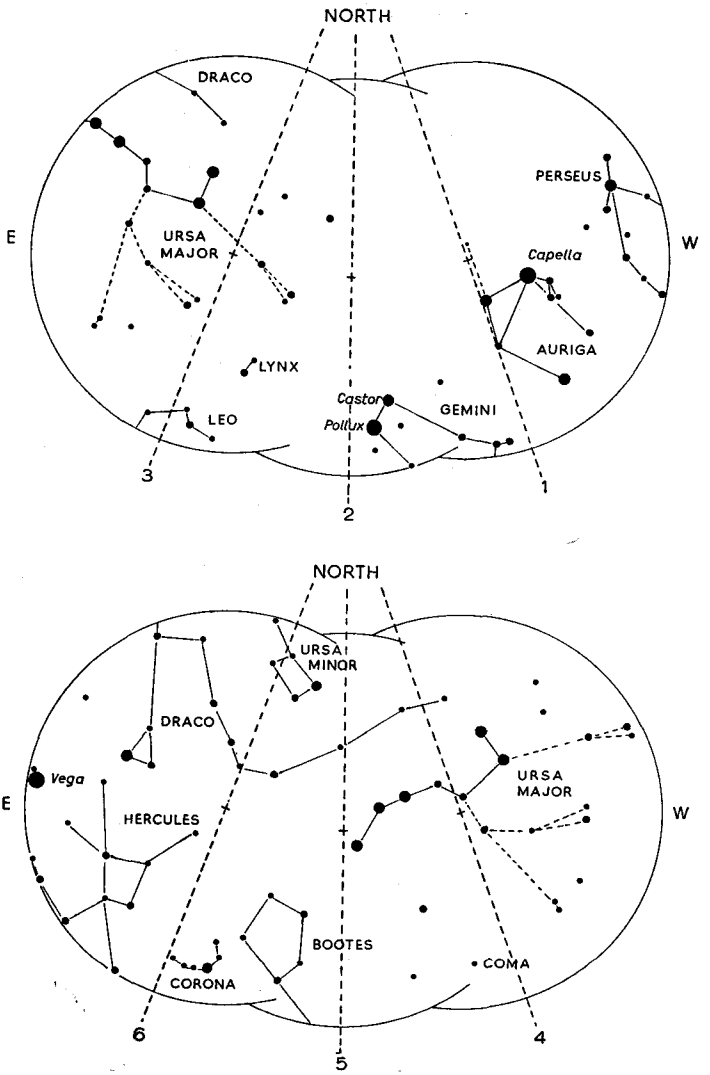




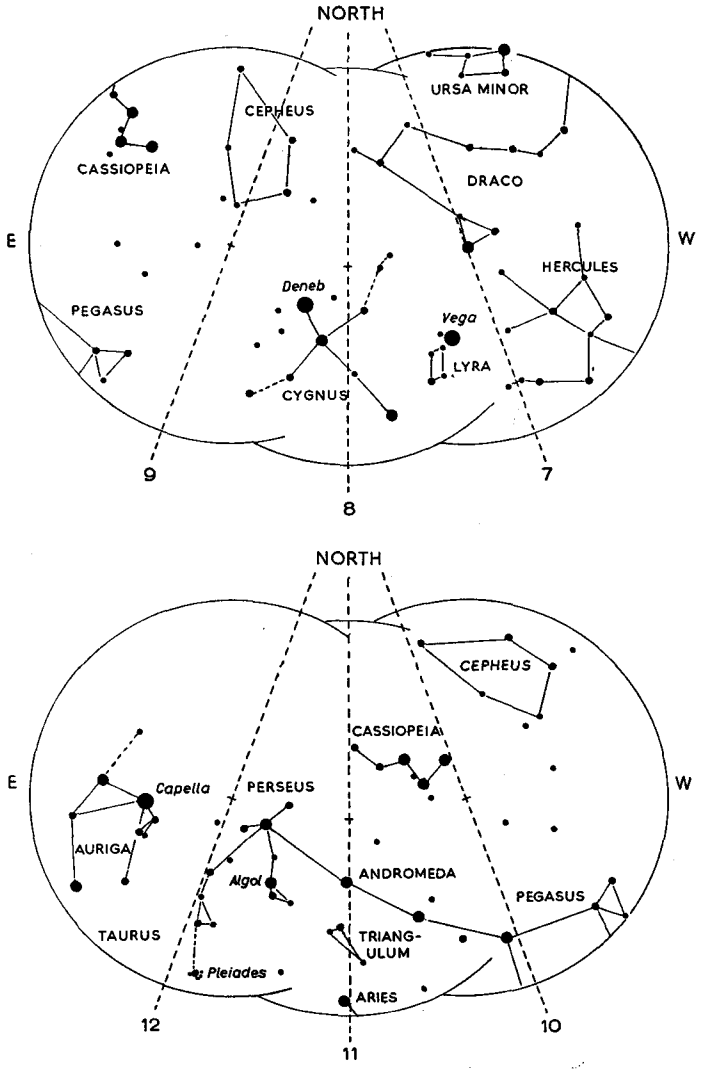
October 6 at 3h	October 21 at 2h	**12R**
November 6 at 1h	November 21 at midnight	
December 6 at 23h	December 21 at 22h	
January 6 at 21h	January 21 at 20h	
February 6 at 19h	February 21 at 18h	







Overhead stars



Overhead stars

The Planets in 1966

DATE		*Venus*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*
January	6	313°	311°	84°	344°	170°	232°
	21	308°	323°	82°	345°	170°	232°
February	6	299°	336°	81°	347°	169°	233°
	21	297°	347°	81°	348°	169°	233°
March	6	303°	358°	82°	350°	168°	233°
	21	314°	9°	83°	352°	167°	232°
April	6	329°	21°	85°	354°	167°	232°
	21	345°	32°	87°	356°	166°	232°
May	6	1°	43°	90°	357°	166°	231°
	21	19°	54°	93°	358°	166°	231°
June	6	37°	66°	96°	0°	166°	231°
	21	54°	76°	100°	0°	166°	230°
July	6	71°	87°	103°	1°	167°	230°
	21	89°	97°	107°	1°	167°	230°
August	6	108°	107°	110°	0°	168°	230°
	21	127°	117°	113°	359°	169°	230°
September	6	147°	128°	116°	358°	170°	230°
	21	165°	137°	119°	357°	171°	231°
October	6	184°	146°	121°	356°	172°	231°
	21	203°	156°	123°	355°	173°	231°
November	6	223°	165°	124°	354°	173°	232°
	21	241°	174°	125°	354°	174°	233°
December	6	260°	182°	124°	354°	174°	233°
	21	279°	190°	123°	354°	175°	234°
Conjunction:							
Superior		Nov. 9	Apr. 29	July 5	Mar. 10	Sept. 13	Nov. 14
Inferior		Jan. 26	—	—	—	—	—
Opposition:		—	(1967 Apr.)	(1967 Jan.)	Sept. 19	Mar. 8	May 12

Mercury moves so quickly among the stars that it is not possible to indicate its position on the star charts at a convenient interval. The monthly notes must be consulted for the best times at which this planet may be seen.

The positions of the other planets are given in the table on the opposite page. This gives the apparent longitudes on dates which correspond to those of the star charts, and the position of the planet may at once be found near the ecliptic at the given longitude.

Examples:

(1) *What is the bright planet, seen rising in the east below and in line with the Twins, Castor and Pollux, at about 2 a.m. (Summer Time) on September 20?*
The time is 1^h G.M.T., and from the table on page 4 the appropriate star chart is seen to be number 11. From this chart the longitude of the planet is seen to be about 120°, and the table opposite indicates that the planet is Jupiter.

(2) *Where can Mars be found on Christmas Day?*
From the table opposite it is seen that Mars is not yet at opposition, and is therefore a morning star; the longitude is given as about 190°. Using charts 2, 3 or 4, as indicated on page 4 for December mornings, Mars is found to be rising in the east in Virgo at about 2^h, and well up in the sky before dawn.

Phases of the Moon, 1966

New Moon			*First Quarter*			*Full Moon*			*Last Quarter*		
d	h	m	d	h	m	d	h	m	d	h	m
Jan. 21	15	46	Jan. 29	19	48	Jan. 7	05	16	Jan. 13	20	00
Feb. 20	10	49	Feb. 28	10	15	Feb. 5	15	58	Feb. 12	08	53
Mar. 22	04	46	Mar. 29	20	43	Mar. 7	01	45	Mar. 14	00	19
Apr. 20	20	35	Apr. 28	03	49	Apr. 5	11	13	Apr. 12	17	28
May 20	09	42	May 27	08	50	May 4	21	01	May 12	11	19
June 18	20	09	June 25	13	22	June 3	07	40	June 11	04	58
July 18	04	30	July 24	19	00	July 2	19	36	July 10	21	43
Aug. 16	11	48	Aug. 23	03	02	Aug. 1	09	05	Aug. 9	12	56
Sept. 14	19	13	Sept. 21	14	25	Aug. 31	00	14	Sept. 8	02	07
Oct. 14	03	52	Oct. 21	05	34	Sept. 29	16	47	Oct. 7	13	08
Nov. 12	14	26	Nov. 20	00	20	Oct. 29	10	00	Nov. 5	22	18
Dec. 12	03	13	Dec. 19	21	41	Nov. 28	02	40	Dec. 5	06	22
						Dec. 27	17	43			

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The Planets and the Ecliptic

The paths of the planets about the Sun all lie close to the plane of the ecliptic, which is marked for us in the sky by the apparent path of the Sun among the stars, and is shown on the star charts by a broken line. The Moon and planets will always be found close to this line, never departing from it by more than about 7 degrees. Thus the planets are most favourably placed for observation when the ecliptic is well displayed, and this means that it should be as high in the sky as possible. This avoids the difficulty of finding a clear horizon, and also overcomes the problem of atmospheric absorption, which greatly reduces the light of the stars. Thus a star at an altitude of 10 degrees suffers a loss of 60 per cent of its light, which corresponds to a whole magnitude; at an altitude of only 4 degrees, the loss may amount to two magnitudes.

The position of the ecliptic in the sky is therefore of great importance, and since it is tilted at about $23\frac{1}{2}$ degrees to the equator, it is only at certain times of the day or year that it is displayed to the best advantage. It will be realized that the Sun (and therefore the ecliptic) is at its highest in the sky at noon in midsummer, and at its lowest at noon in midwinter. Allowing for the daily motion of the sky, these times lead to the fact that the ecliptic is highest at midnight in winter, at sunset in the spring, at noon in summer, and at sunrise in the autumn. Hence these are the best times to see the planets. Thus, if Venus is an evening star, in the western sky after sunset, it will be seen to best advantage if this occurs in the spring, when the ecliptic is high in the sky and slopes down steeply to the north-west. This means that the planet is not only higher in the sky, but will remain for a much longer period above the horizon. For similar reasons, a morning star will be seen at its best on autumn mornings before sunrise, when the ecliptic is high in the east. The outer planets, which can come to opposition and are then in the south at midnight, are best seen when opposition occurs in the winter months. Clearly the summer is the least favourable time to observe the planets, for the ecliptic is always low in the sky on summer nights.

Notes on the Planets in the monthly diagrams

The following general notes on observing the planets are followed by detailed month-by-month accounts of the behaviour of the planets, and of other interesting phenomena. These monthly notes include diagrams of the planetary orbits, and of the apparent movements of the planets at favourable times of the year. Additional notes on other astronomical phenomena will be found on the following pages.

The monthly diagrams of the orbits of the planets are intended to give a picture of the way in which the planets move about the Sun during the month. These diagrams are similar to those that were given many years ago in the old *English Mechanic*, and which were also adopted for some time in the *Journal* of the B.A.A. The motions of the planets are all anti-clockwise, and the movement during the month is indicated by the thickened line; the longitudes are measured from the Equinox, marked 0°. It is difficult to show all the orbits to scale, since the distance of Pluto from the Sun is about a hundred times that of Mercury. For this reason, only the orbits of the inner planets (Mercury to Mars) are shown to scale, those of the outer planets being merely suggested in the diagrams. A line drawn from the Earth to any other planet will give a rough idea of the apparent longitude of that body, but a more accurate value can be obtained from the table on page 32, and this will enable the position of the planet to be found on the monthly star-charts.

The inferior planets, Mercury and Venus, move in smaller orbits than that of the Earth, and so are always seen near the Sun. They are most obvious at the times of greatest angular distance from the Sun (greatest elongation), which may reach 28 degrees for Mercury, or 47 degrees for Venus. They are then seen as evening stars in the western sky after sunset (at eastern elongations) or as morning stars in the eastern sky before sunrise (at western elongations). The succession of phenomena, conjunctions and elongations, always follows the same order, but the intervals

between them are not equal. Thus if either planet is moving round the far side of its orbit its motion will be to the east, in the same direction in which the Sun appears to be moving. It therefore takes much longer for the planet to overtake the Sun – that is, to come to superior conjunction – than it does when moving round to inferior conjunction, between Sun and Earth. The intervals given in the following table are average values; they remain fairly constant in the case of Venus, which travels in an almost circular orbit. In the case of Mercury, however, conditions vary widely because of the great eccentricity and inclination of the planet's orbit.

			Mercury	*Venus*
Inferior conj.	to	Elongation West	22 days	72 days
Elongation West	to	Superior conj.	36 days	220 days
Superior conj.	to	Elongation East	36 days	220 days
Elongation East	to	Inferior conj.	22 days	72 days

The greatest brilliancy of Venus always occurs about a month *before* greatest western elongation (as a morning star), or a month *after* greatest eastern elongation (as an evening star). No such rule can be given for Mercury, because its distance from Sun and Earth can vary over a wide range.

Mercury is not likely to be seen unless a clear horizon is available; it is seldom seen as much as 10 degrees above the horizon in the twilight sky. In general it may be said that the most favourable times for seeing Mercury as an evening star will be in spring, some days before greatest eastern elongation; in autumn it may be seen as a morning star some days after greatest western elongation.

Venus is the brightest of the planets, and may be seen on occasions in broad daylight. Like Mercury, it is alternately a morning and an evening star, and will be highest in the sky when it is a morning star in autumn, or an evening star in spring. Venus is seen to best advantage when it comes to greatest eastern elongation in June; it is then well north of the Sun in the spring months and is a brilliant object in the sunset sky over a long period.

The superior planets, which travel in orbits larger than that of the Earth, differ from Mercury and Venus in that they can be seen opposite the Sun in the sky. The superior planets are morning stars after conjunction with the Sun, rising earlier each day until they

come to opposition. They will then be in the south at midnight, and visible all night. After opposition, they are evening stars, setting earlier each evening until they set in the west with the Sun at the next conjunction. The interval between conjunctions or between oppositions is greatest for Mars (over two years). At the time of opposition, the planet is nearest the Earth, and therefore at its brightest. This change in brightness is most noticeable with Mars, whose distance from the Earth can vary considerably; the other superior planets are at such great distances that there is very little change in brightness from one opposition to another. The effect of altitude is, however, of importance, for at a December opposition the planet will be among the stars of Taurus or Gemini, and can then be at an altitude of more than 60 degrees in southern England. At a summer opposition, when the planet is in Sagittarius, it may only rise to about 15 degrees above the southern horizon, and so make a less impressive appearance.

Mars, whose orbit is appreciably eccentric, comes nearest to the Earth at an opposition at the end of August; it may then be brighter even than Jupiter, but rather low in the sky in Aquarius. These favourable oppositions occur every fifteen or seventeen years (1924, 1941, 1956, 1973), but in this country the planet is probably better seen at an opposition in the autumn or winter, when it is higher in the sky. Oppositions of Mars occur at an average interval of 780 days, and during this time the planet makes a complete circuit of the sky.

Jupiter is always a bright planet, and comes to opposition a month later each year, having moved, roughly speaking, from one Zodiacal constellation to the next.

Saturn moves much more slowly than Jupiter, and may remain in the same constellation for several years. The brightness of Saturn depends on the aspect of its rings, as well as on the distance from Earth and Sun. At present the rings are seen almost edge-on, but the planet is still a bright object.

Uranus, *Neptune* and *Pluto* are hardly likely to attract the attention of observers without adequate instruments, but some notes on their present positions in the sky will be found in the March and May notes.

MONTHLY NOTES, 1966

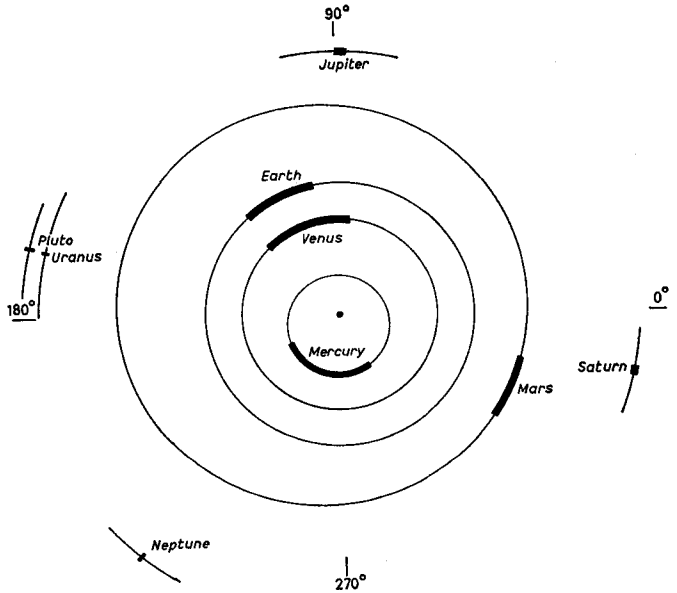
January

Full Moon: January 7 *New Moon:* January 21

Earth is at perihelion (nearest to the Sun) on January 3, its distance from the Sun being then 91,400,000 miles.

Mercury is theoretically a morning star but is too close to the Sun to be seen during the month.

Venus is an evening star at the beginning of the month, and may be seen in the south-west at sunset. On the first of the month it sets about 3 hours after the Sun, but moves rapidly in to inferior conjunction on January 26, after which it becomes a morning star. Venus passes 4 degrees north of Mars on January 8.



Planetary Orbits in January

Mars is an evening star for the first few months of the year. It is not a very conspicuous object (magnitude +1·4) but may be seen among the stars of Capricornus, passing into Aquarius at the end of January. The planet will be at perihelion (nearest the Sun) on January 16, at a distance of 128 million miles. There is no opposition of Mars in 1966.

Jupiter was at opposition in December, and is now a brilliant evening star, visible most of the night. It is moving retrograde in Taurus, between Auriga and Orion, and at the end of the month will be visible in the south in mid-evening; magnitude −2·3. There is no opposition of Jupiter in 1966.

Saturn is also an evening star, setting in the west in mid-evening. It will be found in Aquarius, below the Great Square of Pegasus, and is still the brightest star in the neighbourhood (magnitude +1·3).

The Seasons. The Earth's orbit round the Sun is not circular; it is an ellipse, with slight eccentricity. In early January the Earth is at perihelion (that is to say, its closest point to the Sun), and the distance is reduced to about 91 million miles. At perihelion, in July, the distance is over 94 million miles.

It may seem curious that perihelion occurs in northern winter, but in point of fact the seasons have very little to do with the Earth's changing distance from the Sun. They are caused by the fact that the axis of rotation is tilted at about 23½ degrees; in northern winter, the North Pole is tilted away from the Sun, whereas in northern summer the North Pole is tilted toward the Sun, thus receiving the solar rays much more directly. The slight effects of the varying distance are masked by geographical peculiarities of the Earth, inasmuch as there is a great deal more ocean in the southern hemisphere.

Conditions on the planet Mars are roughly analogous. The axial tilt is between 24 and 25 degrees, much the same as that of the Earth, and so the seasons are of the same general type, though they are much longer (the Martian 'year' is 687 Earth-days.

though the axial rotation is a mere half-hour longer than ours). There is, however, one important difference. The orbit of Mars is considerably more eccentric than that of the Earth, so that the inconstant distance from the Sun plays a fairly major rôle. The southern winters, when Mars is near aphelion, are longer and colder than those of the northern hemisphere. This is shown by the behaviour of the polar caps. The southern cap may become larger than the maximum extent of its northern counterpart – but at Martian midsummer it may disappear completely, whereas the northern cap never does so.

The axial tilts of Saturn and Neptune are not very different from those of Earth, while about Mercury, Venus and Pluto we know very little. Jupiter has a tilt of only about 3 degrees, so that there are no Jovian seasons in the ordinary sense of the word – though the cold is always so intense on the giant planets that seasonal phenomena would make very little difference. Uranus comes into a different category. The tilt amounts to 98 degrees, and is more than a right angle, so that the rotation of the planet is technically 'wrong-way' or retrograde. The seasons must therefore be most peculiar, since each pole will have a night lasting for many years. Uranus takes 84 Earth-years to travel once round the Sun, but only between 10 and 11 hours to spin on its axis, so that there must be something like 65,000 Uranian days in every Uranian year.

The Fading of Mars. Mars, which was so conspicuous in the winter of 1964–5, is now well below the first magnitude, and may easily be mistaken for a star by unwary observers. It may be distinguished by its red hue, and by the fact that it lies in a rather barren region, but during January it is not much brighter than the three stars in the belt of Orion. Its apparent disk is very small, and even large telescopes will show little detail upon it. There is no opposition in 1966; the next will not take place until 1967 April, so that this is a very bad year for observers who are particularly interested in the planet. Between the beginning of March and the end of June, Mars will not be properly visible with the naked eye.

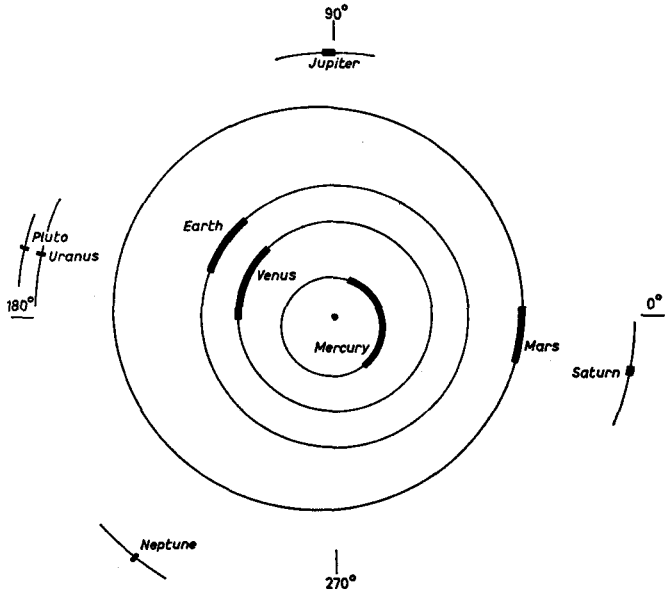
February

Full Moon: February 5 *New Moon:* February 20

Mercury is at superior conjunction on February 6, but at the end of the month it moves out to a favourable eastern elongation, when it may be seen as an evening star (see March notes).

Venus now moves out rapidly from the Sun to become a morning star and by the end of the month it rises 2 hours before the Sun. The brightness increases rapidly, but Venus will not be a very conspicuous object this year, since greatest elongation as a morning star occurs in April; the most favourable circumstances arise in the autumn, as explained on page 34.

Mars is an evening star, but sets only about an hour after sunset. It is now on the borders of Aquarius and Pisces, and in mid-February is in a line below Alpha and Beta Pegasi, the right-hand



Planetary Orbits in February

stars of the Great Square of Pegasus. Mars and Saturn are close together on February 22, but they are then only about 15 degrees from the Sun and very low in the sky.

Jupiter is still a brilliant evening star, but begins to fade to magnitude −2·0. It reaches a stationary point on February 15 in Taurus, and then forms a noticeable triangle with the 'Horns of the Bull', Beta and Zeta Tauri.

Saturn may be seen at the beginning of the month in the south-west for about an hour after sunset, but the planet is now moving rapidly towards conjunction and the period of visibility becomes shorter.

Obscure Constellations. The evening skies in February are still graced by the presence of Orion and his retinue, but there are also some very obscure groups on view; Lynx (the Lynx) and Camelopardus (the Giraffe) high in the sky, and Hydra (the Watersnake) with its companions in the south. Oddly enough, not all these obscure constellations are modern inventions. Hydra was one of the original 48 constellations given by Ptolemy of Alexandria, the last great astronomer of Classical times, who drew up his star-catalogue (based on the earlier work of Hipparchus) in the second century A.D. Hydra has the distinction of being the largest constellation in the sky, but it is also one of the dullest, since the reddish second-magnitude Alphard is its only bright star.

The quondam largest constellation was Argo Navis, the Ship Argo, which lies in the far south, but a few of whose stars may be seen this month above the European horizon. Argo was so immense, and contained so many bright stars, that it was hopelessly unwieldly, and astronomers proceeded to cut up the Ship into several parts, of which the most important are Carina (the Keel), Vela (the Sails) and Puppis (the Poop). Carina, which contains the brilliant Canopus, is below the horizon of Europe or most of the United States; so is Vela, but a small part of Puppis is visible below and to the east of Canis Major.

Cancer (the Crab), lying in the triangle outlined by Regulus,

Procyon and the Twins, is another obscure constellation included in Ptolemy's list; it is notable only because it contains the naked-eye open cluster Præsepe, and because it is contained in the Zodiac. In shape, it somewhat resembles a very dim and ghostly Orion. Its neighbours to the north, Lynx and Camelopardus, were added to the sky-map by Hevelius of Danzig in 1690, but with little justification, since they are remarkably barren both of bright stars and interesting objects. There is even less to be said for two more of Hevelius' additions, Leo Minor (the Little Lion) and Sextans (the Sextant), which border Leo. On the other hand Monoceros (the Unicorn), also formed by Hevelius, is of some note. It lies in the area enclosed by imaginary lines joining Sirius, Betelgeuse and Procyon, and is rich in star-fields and telescopic objects, since the Milky Way runs through it.

Of other obscure constellations, the Zodiacal groups of Capricornus (the Sea-Goat), Aquarius (the Water-carrier) and Pisces (the Fishes) were listed by Ptolemy. So, rather surprisingly, were several small groups in the region of Cygnus, Sagitta (the Arrow), Delphinus (the Dolphin) and Equuleus (the Little Horse); Equuleus is made up only of a small, dim triangle. Also ancient are Corvus (the Crow) and Crater (the Cup), which adjoin Hydra, and are well seen in late winter and early spring. Corvus is made up of a quadrilateral of moderately bright stars, and can be quite prominent, but Crater is very faint, and lacks any definite shape.

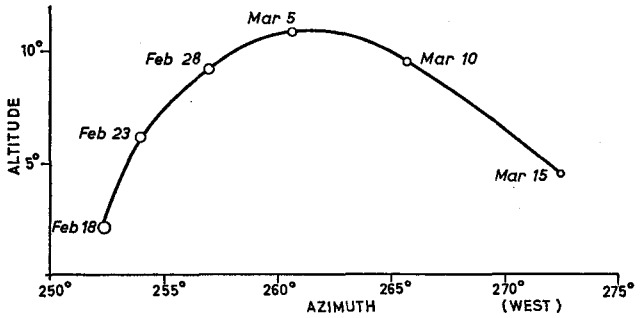
For large numbers of obscure constellations, one must, however, turn to the far south. Near the southern celestial pole, and so invisible from European latitudes, are groups such as Octans (the Octant), Mensa (the Table – originally Mons Mensæ, the Table Mountain) and Horologium (the Clock), which, with others of their kind, seem not to merit separate existence. However, it is most unlikely that any further revisions to the constellations will be made now.

March

Full Moon: March 7 *New Moon:* March 22
Equinox: March 21

Mercury is at greatest elongation east on March 5 (elongation 18 degrees), and this is a good opportunity to see this elusive planet as an evening star in the western sky at sunset. The diagram shows the changes in altitude and azimuth (true bearing from the north through east, south and west) of Mercury on successive evenings at a time when the Sun is 6 degrees below the horizon; this will be about 35 minutes after sunset at this season.

The sizes of the circles give an approximate indication of the expected brightness of the planet; it will be noticed that Mercury is much brighter before the date of greatest elongation.



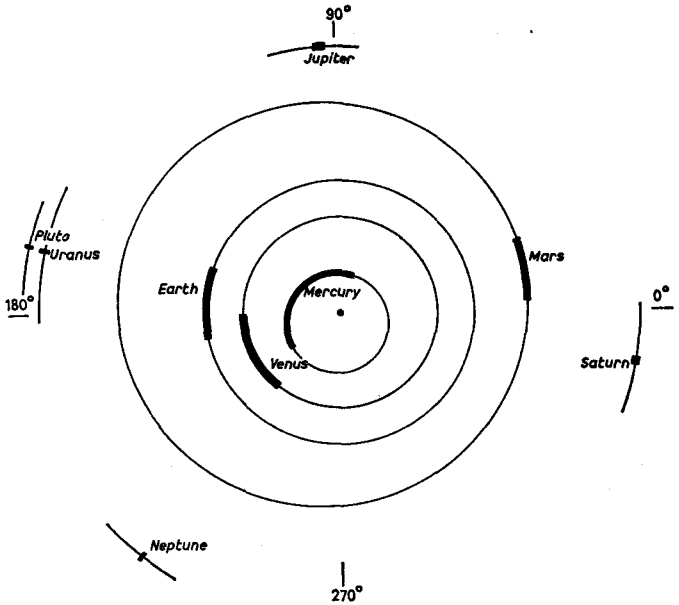
Mercury, February – March

Venus is at greatest brilliancy (magnitude —4·3) on March 1, and then rises about 2 hours before the Sun. The planet is far south of the Sun, and this makes its appearance less impressive, since it will be seen at a low altitude in the south-east at dawn.

Mars is still an evening star in Pisces, but is too near the Sun to be seen.

Jupiter is now moving direct in Taurus, and by the end of the month is again in line with Beta and Zeta Tauri, as it was in

January. It is still a brilliant object, though fading slightly (magnitude −1·8) and it sets in the early hours of the morning.



Planetary Orbits in March

Saturn is in conjunction on March 10, and will not be visible during the month.

Uranus is at opposition on March 8 in Leo, near the star Sigma (see chart on page 73). The magnitude of the planet at this time is +5·7, and it should then be just possible to see it with the naked eye; in a small telescope it appears as a greenish disk. The distance of Uranus at opposition is 1,608 million miles – almost the least it can be, since the planet is nearly at perihelion (see May notes).

Pluto is also at opposition on March 8, but is well north of the ecliptic. Its position is given as a matter of interest in the chart on page 73, but the planet is too faint to be seen with small instruments.

A search in Corvus? Corvus, the Crow, is to be seen in the south, rather low in the sky, during March evenings. It contains few objects of note, but it may possibly be a region in which intensive searches will be made in the future, since there have been suggestions that a tenth, trans-Plutonian planet may lie there.

Six planets were known to the ancients – Mercury, Venus, the Earth itself, Mars, Jupiter and Saturn. In 1781 William Herschel, busy on what he termed 'reviews of the sky', located an unstellar object which he first thought must be a comet, but which proved to be the seventh planet, Uranus. Slight irregularities in the motion of Uranus led to the tracking-down of an eighth planet, Neptune, in 1846. The mathematical computations were carried out by U. J. J. Le Verrier, and the actual discovery was made by J. Galle and H. d'Arrest at Berlin, though it must be added that the English astronomer J. C. Adams arrived at much the same results quite independently.

Further slight irregularities in the movements of the two outer giants led Percival Lowell, best remembered for his theories about Mars, to undertake further computations. Eventually he concluded that still another planet must exist, and this was also the independent view of another American mathematician, W. H. Pickering. Preliminary searches were unsuccessful, but in 1930, long after Lowell's death, the planet Pluto was detected by Clyde Tombaugh at Flagstaff Observatory.

Unfortunately it soon became clear that Pluto was unexpectedly small, and probably of too low a mass to cause measurable perturbations in the movements of Uranus or Neptune. Something was badly wrong; either the accuracy of Lowell's calculations was a complete fluke, or else Pluto was much more massive than its brightness and small apparent diameter indicated. Up to the present time the problem has not been solved, but K. Schütte and other German observers have claimed that another planet may well exist, at a mean distance from the Sun greater than that of Pluto. Their mathematical work indicates that its present position may be among the stars of Corvus. (It is true that Corvus lies outside the Zodiac, but Pluto, too, may move away from the

Zodiacal constellations, since its orbit has the relatively high inclination of 17 degrees. When it reaches aphelion, shortly after the year A.D. 2100, it will be so far south that it will never rise in Britain.)

The trouble is that even if Schütte and his colleagues are right, the trans-Plutonian planet will be very hard to detect. Even if it is a giant, it will be extremely faint, probably well below the twentieth magnitude. It seems that the only hope of finding it would be to use extremely large telescopes in an intensive search – and all telescopes capable of such a thing are fully engaged upon other, more important work. There can be no hope that 'trans-Pluto' will be visible with an instrument of amateur size, or even of the size found in most professional observatories.

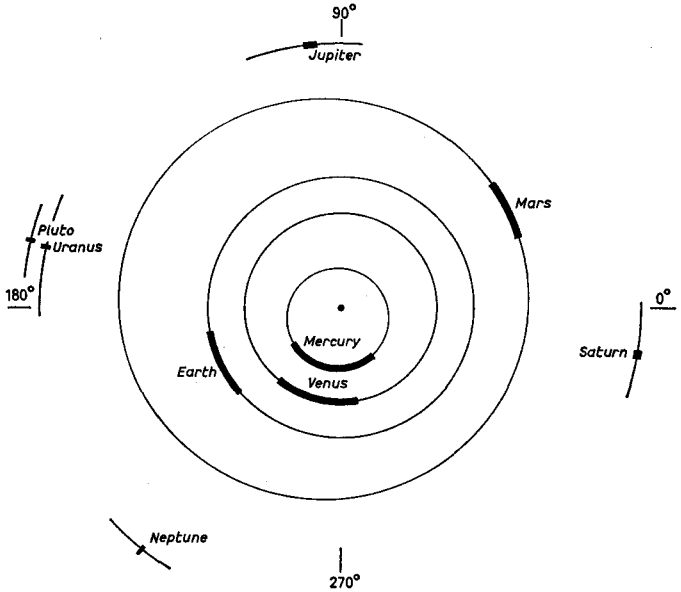
Though the evidence is far from conclusive, 'trans-Pluto' may exist, and it may be found one day; but we must admit that its discovery will be largely a matter of luck. A few plates exposed in the Corvus area would, however, be worth attempting with a giant telescope. Meanwhile, Pluto remains the outermost known member of the planetary system.

April

Full Moon: April 5 *New Moon:* April 20

Mercury reaches greatest western elongation (28 degrees, morning star) on April 18, but it is then well south of the Sun, and does not reach a sufficient altitude to be observed in the dawn sky.

Venus is at greatest elongation west on April 6 (46 degrees), but although a brilliant object, it is still south of the Sun, and therefore low in the dawn sky.



Planetary Orbits in April

Mars is in conjunction on April 29, and will not be visible during the month.

Jupiter is the only bright planet to be seen in the evening sky. By the end of April it sets at midnight, and is then only half as bright (magnitude $-1{\cdot}5$) as it was in January.

Saturn is now a morning star, but rises only a short while before the Sun. The rings are now presented edgewise to the Earth, the plane of the rings passing through the Earth on April 2. This particular disappearance of the rings will not be observed, as the planet is too close to the Sun, but two similar phenomena occur towards the end of the year under more favourable circumstances.

The Lyrids. The Lyrid meteor shower, lasting from April 20 to 22, is very minor compared with the August Perseids, but it is worth looking for – particularly in 1966, as there will be no interference from moonlight. Moreover, the radiant is at a convenient altitude during the early hours of the morning, when most meteors are expected to be seen.

An April Anniversary. Five years ago, on 1961 April 12, the first man entered space. Yuri Gagarin, in the Soviet craft *Vostok I*, made a complete circuit of the Earth, staying aloft for 108 minutes and landing safely on Russian territory. His maximum distance from the Earth's surface was about 200 miles.

Many flights have been made since then, but Gagarin's will be best remembered in history. Several 'bogeys' of space-travel were laid there and then. Gagarin was not killed by the violent acceleration, battered to death by meteorites, affected by zero gravity, or destroyed instantly by cosmic radiation – all of which fates had often been suggested for any Earthmen unwise enough to venture beyond the atmospheric shield. It has been claimed, with some justification, that 1961 April 12 marks the opening of the Space Age, though an argument could also be put forward in favour of the date of the launching of the first artificial satellite on 1957 October 4.

It is worth noting, too, that is now exactly one hundred years since Jules Verne published his classic novel *From the Earth to the Moon*, in which lunar travel was achieved by means of a projectile fired from a space-gun. Of course, the whole space-gun idea is impracticable, two of the reasons being the sudden shock of blast-off, and the heat produced by friction against the air (to say nothing of the fact that a journey to the Moon in such a projectile

would be a one-way trip only). However, Verne made some valuable contributions. He was correct in his ideas of escape velocity, and he had some notion of the effects of weightlessness, though he was admittedly wrong in the details he gave. It is hardly surprising that the Russians have named a large crater on the averted side of the Moon in his honour.

Venus at its brightest. Venus will not be at its best at any time during 1966, but it is conspicuous during the early mornings in April. It is, as always, far brighter than any other star or planet, but it lies well to the south of the celestial equator, and so cannot be seen against a dark background.

This does not much matter to the serious observer, since there is very little point in studying Venus with a telescope when it is shining brilliantly down. There is too much dazzle, and the low altitude will make conditions intolerable. If Venus is to be observed properly, it must be studied in daylight, when the sky is bright and the planet is high up. Though Venus is sometimes visible with the naked eye when the Sun is well above the horizon, a telescope fitted with setting circles is a practical necessity. Random 'sweeping' for Venus during daylight is emphatically not to be recommended, since there is always a chance that the Sun will enter the telescopic field by mistake – with results which are certain to be disastrous.

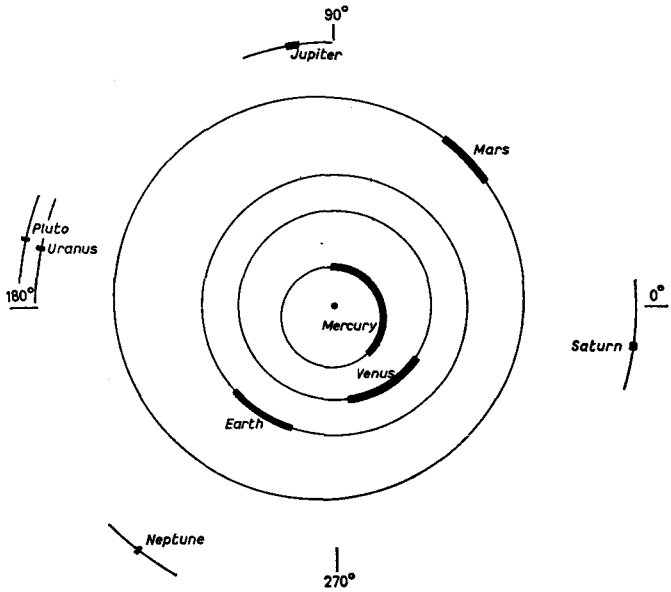
May

Full Moon: May 4 *New Moon:* May 20

Mercury is at superior conjunction on May 27, and will not be visible during the month.

Venus is still far south of the Sun, and rises in the east only about an hour before sunrise. Venus will be near Saturn on May 1.

Mars is now a morning star, but is still too close to the Sun to be visible.



Planetary Orbits in May

Jupiter now passes into Gemini, and sets to the north of west in mid-evening. The chart on page 70 shows that the planet passes north of the stars Eta and Mu Geminorum at the end of the month, and as the figure of Gemini sets in an almost vertical

position, with *Castor* and *Pollux* side by side at the top, Jupiter will be seen at the bottom right of the figure.

Saturn now becomes visible as a morning star, rising more than 2 hours before sunrise at the end of the month, when it passes into Pisces. The rings are now a very thin line, the south side of the ring being presented to the Earth, while the Sun still shines on the north side. In a small telescope, the rings will probably be quite invisible.

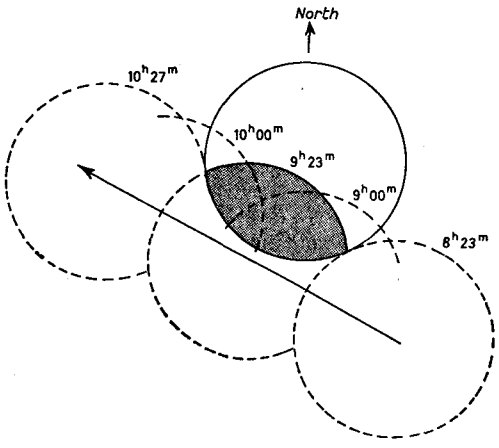
Uranus is at perihelion on May 20 at a distance of 1,700 million miles from the Sun. This is about 167 million miles less than the distance at aphelion, as in the years 1924 and 2008.

Neptune is at opposition on May 12 in Libra. The planet is not visible to the naked eye (magnitude +7·7) but may be seen in a small telescope as a greenish disk. At opposition, the distance of Neptune from the earth is about 2,726 million miles.

A penumbral eclipse of the Moon will take place on May 4 – see page 80.

An annular eclipse of the Sun on the morning of May 20 will be visible in the British Isles as a partial eclipse. The accompanying diagram shows the course of the eclipse as seen from a point in southern England (latitude 52 degrees, on the Greenwich meridian), but the appearance will be very similar in other parts of the country. The Moon moves to the left across the lower half of the Sun's disk, and the times of several stages of the eclipse are shown. See also page 80.

Eclipses of the Sun. The eclipse of the Sun on May 20, annular from the Sahara to Siberia, will be seen as a partial eclipse in Britain. It will be well worth watching, but an important warning should be repeated here: On no account look at the Sun direct through a telescope, even with a dark filter attached to the eyepiece. It is also unwise to look straight at the Sun with the naked eye for more than a second or so at a time. During the last large partial eclipses visible from England (1954 and 1961) quite a number of



Eclipse of the Sun, 1966 May 20

people damaged their eyes in this way, and the warning cannot be given too often.

At an annular eclipse, the Moon is too far from the Earth to cover the Sun completely, and at mid-eclipse the dark lunar disk is surrounded by a ring of the Sun's bright surface or photosphere. The corona and prominences cannot be seen with the naked eye, and to professional astronomers an annular eclipse is of very minor importance compared with a total eclipse. It is therefore unlikely that any full-scale expeditions will be dispatched this month to the central track, though no doubt some interested observers will go.

England has been badly served by total eclipses in recent times. The last occurred in 1927, while the next will not be until 1999, when the track of totality will cross Cornwall.

Coma Berenices. The interesting constellation of Coma Berenices (Berenice's Hair) is now almost at the zenith during evenings, between the Great Bear on the one side and Virgo on the other. It contains no star above the fourth magnitude, but there are a

great many faint ones, and the whole region gives an impression of a large, extended star-cluster.

Coma is extremely rich in galaxies, which are very common here and in the adjacent part of Virgo. It therefore receives much attention from professional astronomers, while amateurs will find it well worth sweeping with low powers.

Neptune. On May 12 Neptune reaches opposition. It lies in Libra, and is so well south of the celestial equator; even so it is a conspicuous telescopic object, with a magnitude of 7·7. It looks quite unlike a star, appearing as a small, dim disk.

Neptune has a diameter of 27,700 miles. It is rather smaller than its 'twin', Uranus, but is denser and more massive. Even large telescopes will show little surface detail, and altogether our information about it is decidedly meagre. Its period of revolution round the Sun is 164·8 years, and its axial rotation period probably in the region of 14 hours.

Neptune has two satellites. One, Triton, is a large body perhaps 3,000 miles in diameter (as large as Mercury); the other, Nereid, is a dwarf, and excessively difficult to detect. Triton, however, is brighter than any of the five satellites of Uranus, and a moderate telescope will show it. There have been suggestions, so far unconfirmed, that it has an appreciable methane atmosphere similar to that of Saturn's sixth satellite, Titan. It has also been suggested that the planet Pluto is nothing more or less than an ex-satellite of Neptune, which broke free and moved off along an independent orbit. Certainly Pluto and Triton seem to be comparable in size.

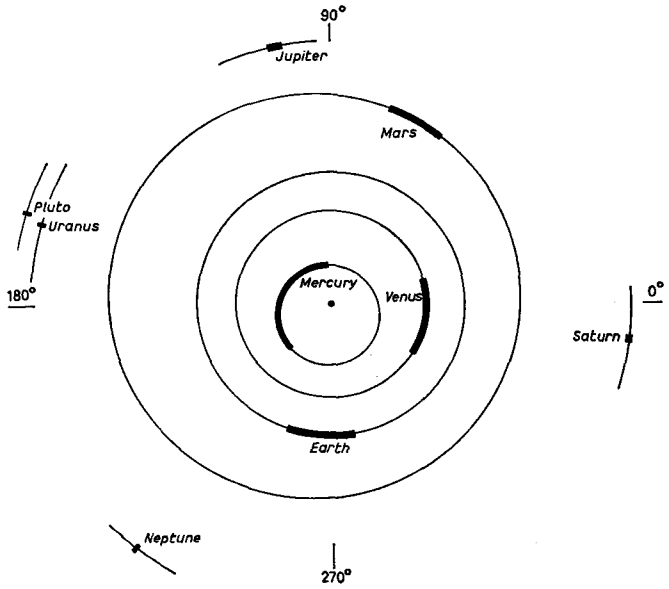
June

Full Moon: June 3 *New Moon:* June 18
Solstice: June 21

Mercury is at greatest elongation east on June 30 (26 degrees, evening star) but is then well south of the Sun, and will be lost in the bright sunset sky.

Venus is now moving more rapidly north, and begins to be seen in the east for a longer period before sunrise. The distance from the earth is increasing, however, and the brightness diminishing; the planet is only half as bright (magnitude −3·5) at the end of the month as it was in early January or early March.

Mars moves out very slowly from the Sun, and by the end of the month it rises about an hour before sunrise. If it is at all visible, it



Planetary Orbits in June

will be seen north of east, in Taurus. Because of its eccentric orbit, Mars is actually at its farthest from the Earth in mid-June (232 million miles) and not at its conjunction with the Sun in April.

Jupiter is now moving towards conjunction and sets shortly after the Sun, so that it is lost in the bright sunset sky.

Saturn is now well seen as a morning star, and rises at midnight at the end of the month. It is moving direct in Pisces, below the Great Square of Pegasus (see chart on page 66) and its brightness is increasing (magnitude +1·3 to +1·2). On June 15 the plane of the rings passes through the Sun, and after this the south side of the rings is presented to both Earth and Sun.

The rings of Saturn. Special attention should be paid to Saturn this month. The planet now rises early enough to become high before dawn, and the ring-phenomena are most interesting. Reference should be made to Dr Joel Goodman's article given later in this *Yearbook*.

Mars at its farthest. It is said, with truth, that Venus and Mars are the nearest planets to Earth, since Venus may approach within 25 million miles of us and Mars well within 35 million miles. Yet since both these worlds move round the Sun, not round the Earth, they do not remain conveniently close in the same way that the Moon does. This month Mars lies on the far side of the Sun, and is therefore very remote – more than nine hundred times as distant as the Moon! Even when it becomes visible again, later in the summer, it will show a very small disk. Its diameter (4,219 miles) is only about twice that of the Moon, and detailed observations can be made only for a few months to either side of opposition.

Sagittarius. Low down in the south during June evenings may be seen the ancient Zodiacal constellation of Sagittarius, the Archer. It is a much brighter group than is usually realized by Britons, since it contains several notable stars, one of which (Epsilon Sagittarii, or *Kaus Australis*) is only slightly below the first magni-

tude. Also conspicuous is Sigma Sagittarii (*Nunki*), which is farther north, and therefore more accessible to Europeans.

Sagittarius has no really distinctive shape. One way to locate it is to use *Deneb* and *Altair* as direction-finders, but there should be no difficulty if Scorpio is on view; Sagittarius lies well to the east of the brilliant red *Antares*, and will be found easily.

Seen from more southerly latitudes, such as Arizona or California, Sagittarius makes a brave show, and can hardly be overlooked. It also contains numerous interesting objects for telescopic workers.

Mythologically it has been identified with Chiron, the wise Centaur who acted as tutor to Jason and others of the Argonautic expedition in quest of the Golden Fleece – though it has also been said that Chiron merely invented the group to act as a guide to the great ship's navigator. In any event, it is one of Ptolemy's original constellations. It is the most southerly group in the Zodiac; like Scorpio, parts of it remain permanently below the European or New York horizon.

Twilight. During the longest days, in June, twilight lasts all night in the latitude of London, and during the period of full moon there is no proper darkness. This is merely inconvenient to the professional astrophysicist who is anxious to continue with his work, but to observers further north, where the days are longer still, it can be a really serious handicap. For instance, it is impossible to carry out any stellar work at the Pulkovo Observatory, Leningrad; the sky is too bright. The famous Leningrad 'white nights' may be beautiful, but astronomers do not welcome them, and it is understandable that the Russians are now moving their main telescopes to sites further south in Soviet territory.

July

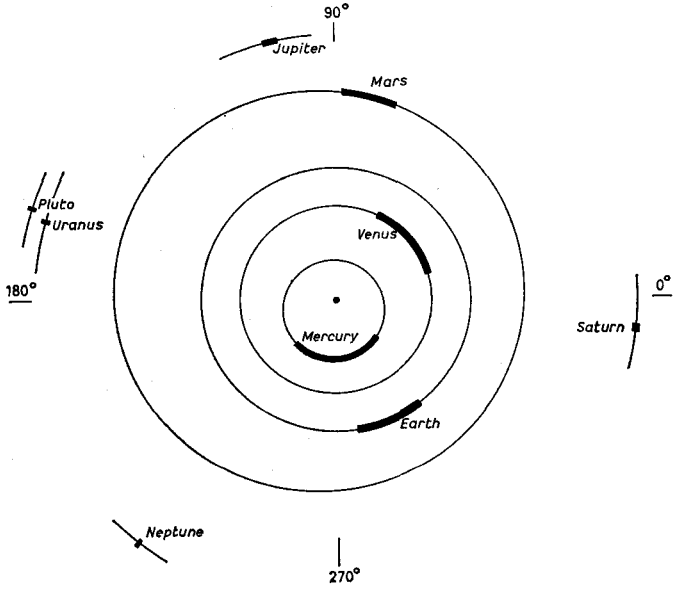
Full Moon: July 2 *New Moon:* July 18

Earth is at aphelion (farthest from the Sun) on July 5, when its distance from the Sun is 94,500,000 miles.

Mercury will not be seen during July, since it comes to inferior conjunction on July 28.

Venus is visible for more than 2 hours before sunrise in mid-July, but its brightness is now at a minimum, reaching magnitude −3·3, and remaining at about the same value for the rest of the year. Venus passes 4 degrees north of *Aldebaran* on July 4, and by the end of the month reaches its most northerly declination in Taurus.

Mars also reaches its most northerly point this month, passing into Gemini on July 10. It is now almost of the second magnitude



Planetary Orbits in July

(+1·8) and both *Castor* and *Pollux* may be seen to be brighter than this. By the end of July, Mars rises more than 2 hours before the Sun.

Jupiter is in conjunction on July 5, and then becomes a morning star. Since the Sun rises later, and Jupiter earlier each day, the planet soon becomes visible in the dawn sky to the north of east, and by the end of the month it rises about 2 hours before the Sun.

Saturn reaches a stationary point in Pisces on July 12 and then begins its retrograde movement before opposition; it now rises in mid-evening, and its brightness increases to magnitude +1·1.

Lyra. *Vega*, or Alpha Lyræ, occupies the overhead position during July evenings, and its brilliant bluish light makes it stand out prominently. It is the only really bright star in Lyra (the Lyre or Harp), but the constellation, though small, contains more than its fair share of interesting subjects.

Particularly noteworthy is the 'double-double' or quadruple star Epsilon Lyræ, close to *Vega*, described in James Muirden's article in the stellar section of this *Yearbook*. Ordinary-sighted people can see the two main components with the naked eye, and a 3-inch refractor will show all four. Zeta Lyræ is also a wide, easy telescope double.

Beta Lyræ, sometimes still known by its old proper name of *Sheliak*, is a remarkable system. It is an eclipsing binary, but quite different from Algol in Perseus; variations are continuous, and there are alternate deep and shallow minima, one of magnitude 3·8 and the other of magnitude 4·4. Maximum is only 3·4, so that Beta is never a prominent naked-eye object; at its brightest it is about equal to *Megrez*, the faintest of the seven main stars in the Great Bear.

The two components are so close together that they almost touch, and so cannot be seen separately. Each must be stretched out into the shape of an egg, while there is an extensive gaseous envelope. Beta Lyræ has received an immense amount of attention from astrophysicists, since it is by far the brightest member of its

class. The variations may be followed with the naked eye; the nearby Gamma Lyræ (3·2) is a convenient comparison star.

Between Beta and Gamma lies the celebrated Ring Nebula, Messier 57, the brightest of all the planetaries. It was described in C. A. Ronan's article on 'Planetary Nebulæ' in the 1964 *Yearbook*. It is below naked-eye visibility, but a 3-inch refractor will show it distinctly, and it is easy to find in view of its position midway between Beta and Gamma. The central star is a very elusive object, and requires large apertures. R Lyræ, forming a triangle with *Vega* and Delta Cygni in the 'cross', is an M-type long-period variable; at maximum it may reach magnitude 5·7, and is prominent with binoculars, though it falls to the 12th magnitude at minimum. The period is 310 days. Like many long-period variables, it is very red.

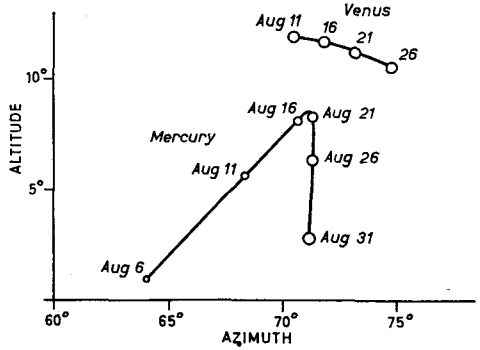
Beta Cygni. *Albireo* or Beta Cygni is another double, also described in Muirden's article in this *Yearbook*. It is particularly beautiful, since the primary is golden-yellow and the companion bluish or greenish; it is moreover wide enough to be split with small apertures. Beta Cygni is a very luminous star, lying at a distance of over 400 light-years. It is involved in the Milky Way, and this whole area will repay sweeping with a low power.

The name Cygnus is Latin for 'Swan', but a more popular and apt name for the constellation is the Northern Cross. Certainly Cygnus is a better cross than the famous southern cross, Crux, but the symmetry is spoiled by Beta, which is fainter than the other members of the pattern and is also further away from the centre of the cross (Gamma Cygni). It is worth noting that Beta lies not very far from an imaginary line joining *Vega* to *Altair*.

August

Full Moon: August 1 and 31 *New Moon:* August 16

Mercury is at greatest elongation west on August 16 (19 degrees) and there is then another opportunity to see this planet as a morning star. Venus is in the same part of the sky, but there should be little risk of confusion, Venus being much brighter and farther out from the Sun. The diagram shows the changes in altitude and azimuth of Mercury on successive mornings when the Sun is 6 degrees below the horizon; this is about 35 minutes before sunrise at this time of year. The changes in brightness are roughly indicated by the sizes of the circles; it will be seen that Mercury is brightest after the date of western elongation. The relative positions of Venus on four dates are also shown, but it must be remembered that Venus is about 100 times as bright as Mercury on August 6, about 30 times as bright on August 16, and nearly 10 times as bright on August 31.

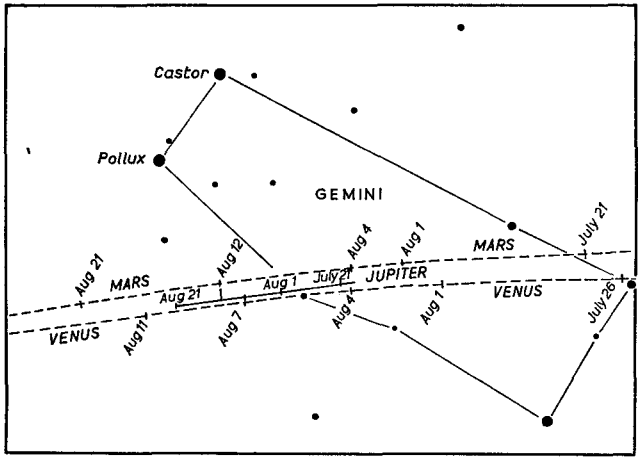


Mercury – August

Venus is now moving south again and its period of visibility before sunrise decreases as the planet moves in towards superior conjunction. Venus will be seen close to Mars on August 4 and passes close to Jupiter on August 7 (see notes and diagram below).

Mars is moving rapidly through Gemini, and passes into Cancer

at the end of the month, when it rises more than 3 hours before sunrise. Both Venus and Jupiter will be in the same part of the sky as Mars, and the relative movements of the three planets are shown in the accompanying diagram. It will be seen that there are three conjunctions of some interest: Venus with Mars on August 4, Venus with Jupiter on August 7, and Mars with Jupiter on August 12. The magnitude of the three planets are Venus −3·3; Mars +1·8; Jupiter −1·4, so that Mars will be difficult, if not impossible, to see in the bright dawn sky without some optical aid.

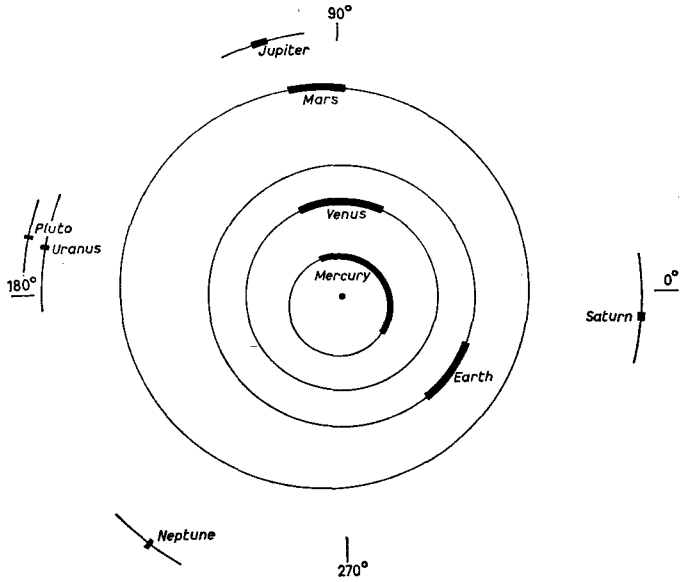


Mars, Venus and Jupiter

Jupiter is a morning star in Gemini, and by the end of the month rises in the east more than 3 hours before the Sun. The conjunctions with Venus and Mars that occur during the month are described above.

Saturn is moving retrograde in Pisces, and is growing noticeably brighter as it approaches opposition (magnitude +1·0 to +0·9). It now rises shortly after sunset, and is visible throughout the night.

Mercury. With clear skies in the early morning, there should be little trouble in finding the elusive planet Mercury with the naked



Planetary Orbits in August

eye during mid-August. It is not, in point of fact, at all faint; if it could be seen against a dark background it would be extremely prominent, and the main trouble is its low altitude. The newcomer to astronomy may have to spend some time in searching for it – but when he finds it, he will wonder how he could ever have overlooked it. The colour is said to be pinkish, though to most eyes Mercury will probably seem white.

There is a legend that Copernicus, the great theorist who published the famous book which marked the real start of the controversy about the plan of the Solar System, never saw Mercury at all, owing to mists rising from the River Vistula near his home. This is probably nothing more than a story. It is true that Copernicus lived in pre-telescopic times, but he spent some time in Italy, and he must undoubtedly have seen Mercury at intervals. Certainly the ancients knew all about the planet; it has been known since the first astronomical records were kept.

Yet if Mercury, with a diameter of 2,900 miles and a distance from the Sun of 36,000,000 miles on the average, is far from conspicuous, there would seem to be little hope of observing any smaller planet at a still lesser distance from the Sun. During the last century such a planet was widely believed to exist; it was even given a name (Vulcan), and Le Verrier, the great French astronomer whose mathematical work was responsible for the tracking-down of Neptune, regarded it as an established member of the Solar System. However, the only chance of seeing it would be either during a total eclipse of the Sun, or else when the planet passed across the Sun's disk in transit. Vulcan has now been so consistent an absentee that it has been relegated to the status of a ghost, and no modern astronomers believe it to exist. However, one asteroid (Icarus) can pass well within 20,000,000 miles of the Sun, and there is no reason to doubt that other small asteroids do likewise. Small worlds of such a type would not be observable in transit.

The Milky Way. During August evenings the Milky Way passes across the zenith, and is a magnificent sight. It has been the subject of many legends, but it was only when Galileo first turned a telescope to the sky that its true nature was recognized.

Strangely enough, the stars in the Milky Way are not crowded close together. The effect is simply one of line-of-sight, since in the direction of the Milky Way we are looking along the main plane of the Galaxy.

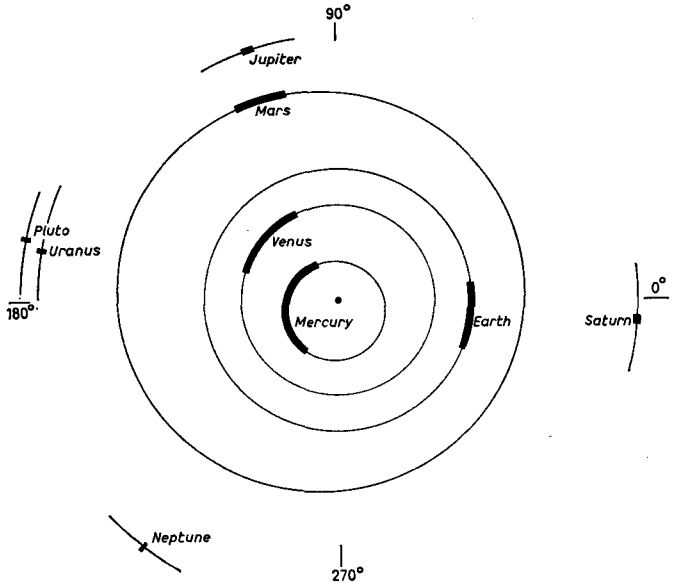
The Perseids. August is the month associated with the Perseid meteors. The display begins about July 27, and goes on until August 17; it will be seen to advantage during the second week in August 1966, since the Moon will have ceased to interfere. The Perseids are always rich; unlike the November Leonids, they never fail us – and anyone who stares up at the night-sky for a few minutes near peak activity will be very unlucky not to see several bright meteors. Early mornings are the best times for meteor-watching, one reason being that the radiant is then higher up.

September

New Moon: September 14 *Full Moon:* September 29
Equinox: September 23

Mercury is at superior conjunction on September 10 and is too close to the Sun to be seen during the month.

Venus is still a morning star, but its period of visibility before dawn is slowly decreasing; by the end of the month it rises only about an hour before sunrise.

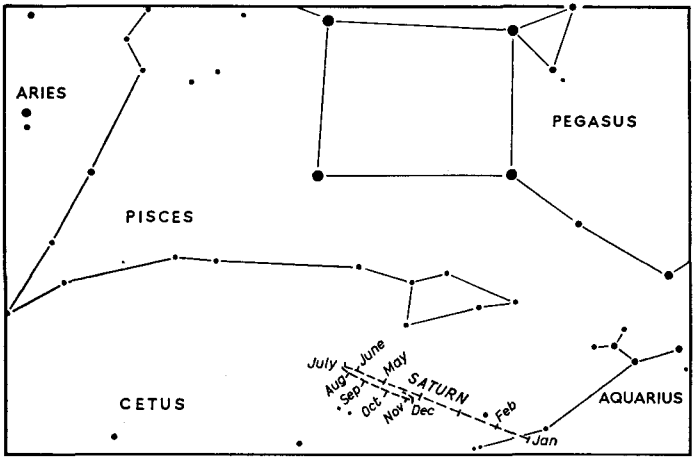


Planetary Orbits in September

Mars is a morning star in Cancer, and in early September it passes close to the cluster *Præsepe* (M44). On September 22 it passes into Leo, and by the end of the month it will be found near the Sickle, not far from the star *Regulus*.

Jupiter passes into Cancer in mid-September, and rises about midnight at the end of the month, when it will be seen below and in a line with the Twins, *Castor* and *Pollux*. The planet continues to grow brighter (magnitudes $-1{\cdot}5$ to $-1{\cdot}6$). With the coming of the longer nights the owner of a small telescope will find both interest and pleasure in watching the phenomena of Jupiter's four great satellites. The eclipses are easiest to observe, and during 1966 all four satellites are eclipsed by Jupiter at each revolution.

Saturn is at opposition on September 19, at a distance of 796 million miles. It is then at its brightest (magnitude $+0{\cdot}8$) and will be in the south at midnight, when it may be compared with the bright southern star *Fomalhaut* (magnitude $+1{\cdot}3$). At the end of the month, Saturn moves back into Aquarius. At this opposition, the rings are seen almost edge-on, and may be quite difficult to see in a small telescope.



Saturn

The Zodiacal Light. Of the faint, elusive glows of the night-sky, the Zodiacal Light is one of the most intriguing. It is never easy to see from Britain, but is most likely to be glimpsed in early mornings

in September. The altitude is the same during late evenings in March, but then, of course, there is a greater probability of cloud.

The Zodiacal Light takes the form of a delicate cone of light, extending along the ecliptic; it is to be seen only when the Sun is below the horizon, and yet not many degrees out of view. When the Sun is only just invisible, the sky is too light; when the Sun sinks far enough for the sky to become really dark, the Zodiacal Light becomes too low to be observed. Obviously, then, it has to be caught at just the right moment.

Unlike the aurora, it originates well beyond the top of the Earth's atmosphere, and seems to be due to the light reflected from a layer of fine interplanetary matter spread out in the main plane of the Solar System. At its best, it may be comparable in brightness with the Milky Way.

Even more elusive than the Zodiacal Light is the Gegenschein or Counterglow, also best seen in September. The Gegenschein, first described accurately by the Danish astronomer Theodor Brorsen in the 19th century, is a faint, hazy patch of light, always exactly opposite the Sun in the sky, and covering an area which may equal that of the Square of Pegasus. The slightest haze, moonlight, or artificial illumination is enough to conceal it, and from England it is excessively difficult to see. The Gegenschein is really the brightest part of the Zodiacal Band, a dim, parallel-sided extension of the Zodiacal Light. It too must be due to thinly-spaced interplanetary material, though its exact origin is still a matter for dispute.

The Square of Pegasus. Throughout autumn, the Square of Pegasus dominates the southern part of the evening sky. Its stars are not remarkably brilliant – all four are between the 2nd and 3rd magnitudes – but they make up a striking pattern, particularly as they lie in a region which is otherwise rather barren.

The upper left-hand star of the Square used to be known as Delta Pegasi, but has now been transferred to the neighbouring constellation of Andromeda, as Alpha Andromedæ; its proper

name, still often used, is *Alpheratz*. The upper right-hand star of the Square, Beta Pegasi or *Scheat*, is a Red Giant. Like many of its kind, it is variable; the magnitude range is from 2·3 to 2·8, and there is a very rough period of from 35 to 40 days. Alpha Pegasi (2·5) at the bottom right of the Square, and Gamma Pegasi (2·9) at the bottom left, act as good comparison stars, and the light-changes may be followed with the naked eye.

It is interesting to count the number of faint stars visible inside the Square without optical aid. There are not many of them, though the area covered is considerable.

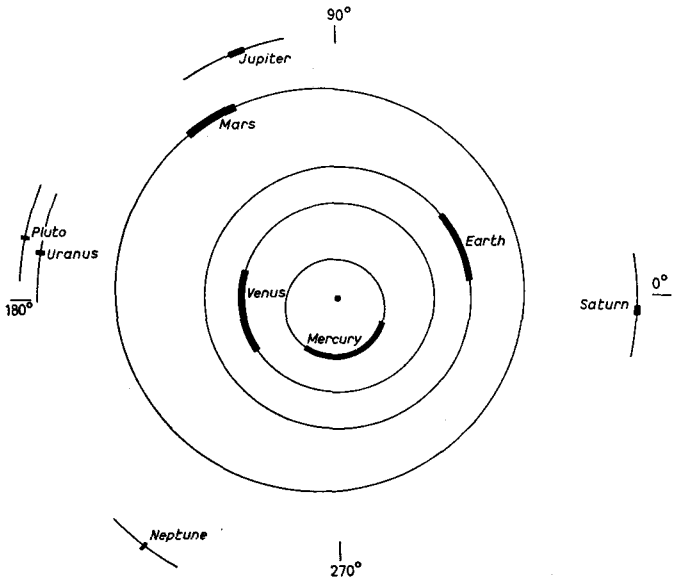
Well below the Square, close to the English horizon, is Fomalhaut in Piscis Austrinus, the southernmost of the first-magnitude stars visible from Europe or the main United States. It is described in the article given in the stellar section of this *Yearbook*.

October

New Moon: October 14 *Full Moon:* October 29

Mercury is at greatest eastern elongation on October 26, but is then well south of the Sun and will not reach a sufficient altitude to be seen as an evening star.

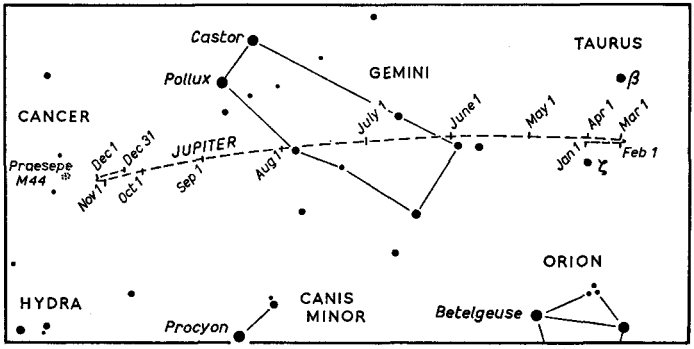
Venus is moving steadily in to superior conjunction and is now too close to the Sun to be readily visible.



Planetary Orbits in October

Mars continues to rise about the same time every morning ($1^h\ 30^m$) this being a characteristic of the rapid motion of this planet. It is now seen near the Sickle of Leo, and on October 11 it passes about a degree north of the star *Regulus*, which will be seen to be decidedly brighter than Mars (magnitudes: Mars +1·8, *Regulus* +1·3).

Jupiter now rises before midnight and continues to grow brighter (magnitudes −1·6 to −1·7). It is moving direct in Cancer, a brilliant object in a barren part of the sky.



Jupiter 1966, Autumn

Saturn is still moving retrograde in Aquarius, and will be seen in the south in the late evening, below the Great Square of Pegasus. It is now fading a little (magnitudes +0·9 to +1·1) as its distance from the Earth increases. The plane of the rings passes through the Earth for the second time this year on October 29, and after this the north side of the rings is visible, while the Sun continues to shine on the south side. Theoretically this should render the rings invisible, but in fact they can still be seen with moderate telescopes.

A penumbral eclipse of the Moon occurs on October 29 (see page 80).

The penumbral eclipse of the Moon. Because the Sun is a disk, and not a point source of light, there is an area of penumbral or 'partial' shadow to either side of the main cone of shadow cast by the Earth. At each proper lunar eclipse, the Moon must first pass through the penumbra, and a slight but perceptible dimming is visible. Observations made at the total eclipse of December 1964 by members of the Lunar Section of the British Astronomical Association showed that the effects were detectable some thirty minutes before the Moon passed into the main cone.

When the Moon misses the actual cone, but enters the penumbra, we see a penumbral eclipse. This will occur on October 29, but unfortunately it will not be visible from Europe; it will, however, be seen over the whole of the North American continent, and the Moon will only just avoid entering the main shadow-cone. A distinct dimming of the disk should be seen. The effect will not be at all striking, but it will be far from devoid of interest.

Pallas. The minor planet Pallas – apart from Ceres, the largest member of the asteroid swarm, with a diameter of 280 miles – comes to opposition this month. It lies in Cetus (the Whale), well away from the Zodiac. Pallas has an orbital inclination of 34 degrees, which is very high for a senior asteroid, though smaller members of the swarm have paths which are even more sharply tilted. With binoculars or small telescopes it is an easy object, but looks exactly like a star, though over two or three nights its motion will betray it.

Conjunction of Mars and Regulus. On October 11 Mars will be very close to *Regulus* in Leo, but the two cannot be confused; Mars is half a magnitude the fainter, and its red hue will contrast sharply with the whiteness of *Regulus*.

Regulus is one of only four first-magnitude stars which lie near enough to the ecliptic to be occulted by the Moon or planets; the other stars are *Antares*, *Aldebaran*, and *Spica*. Such occultations of bright stars by planets are excessively rare, but there was a famous case on 1959 July 7, when *Regulus* was hidden by Venus. The phenomenon took place in the early afternoon, but was widely observed, and proved to be of value; the fading of Regulus before being covered by the solid body of Venus gave information about the extent of the planet's refracting atmosphere. It will be many years before another occultation of this sort takes place, and even occultations of fainter stars by planets are uncommon. There are also recorded instances in which one planet has been hidden by another; Venus occulted Mars in 1590 and Mercury in 1737, while in 1859 Venus and Jupiter were so close together that optical aid was necessary to separate them. In 1955

Jupiter and Uranus lay close together, so that for a while Uranus appeared in the guise of an extra Jovian satellite! In November 1966, Uranus will be within a degree or so of Mars.

Occultations of stars by the Moon are, of course, quite common. It is worth noting that a new series of lunar occultations of Antares will begin in 1967.

November

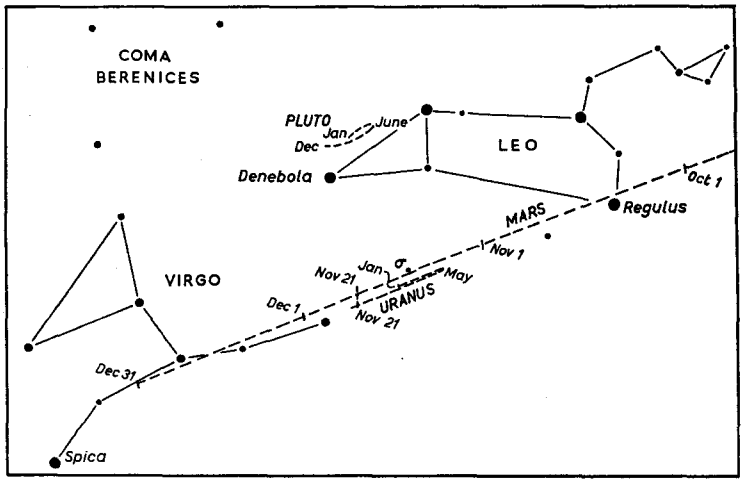
New Moon: November 12 *Full Moon:* November 28

Mercury is at inferior conjunction on November 17, and will not be visible during the month.

Venus is at superior conjunction on November 9. After this date it is theoretically an evening star, but is still too close to the Sun to be seen.

Mars continues to rise in the early hours of the morning but is slowly growing brighter (magnitude +1·7 to +1·5) as the distance from the Earth decreases. The planet is moving direct in Leo and at the end of the month passes into Virgo where it will be found for the next few months. Mars passes 1 degree north of Uranus on November 21 (see diagram below).

Jupiter reaches a stationary point on November 21 about 2 degrees west of the cluster *Præsepe* (M44) in Cancer; this is its

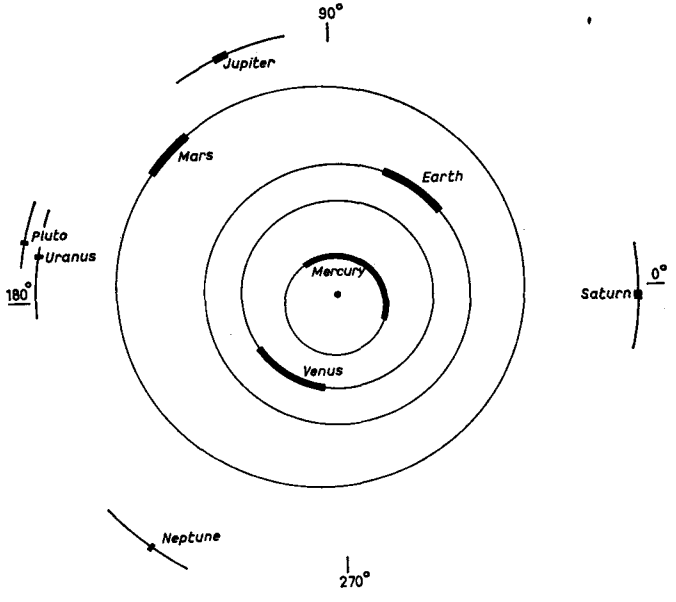


Mars, November

most easterly position in 1966, and it then begins to move back towards Gemini. Jupiter now rises well before midnight, and its brightness continues to increase (magnitude $-1{\cdot}7$ to $-1{\cdot}9$).

Saturn also reaches a stationary point on November 27, and after this its motion is again direct. The planet sets shortly after midnight and is now noticeably less bright than it was at opposition (magnitude $+1{\cdot}1$ to $+1{\cdot}2$).

A total eclipse of the Sun takes place on November 12, but is not visible in the British Isles (see page 80).



Planetary Orbits in November

The total solar eclipse. The only total solar eclipse of 1966 is an awkward one, since it is confined to parts of South America; nothing at all will be seen from Europe. No doubt expeditions will be dispatched to the central track of the eclipse, ready to take

advantage of the brief moments during which the Sun is blotted out and the glorious, pearly corona flashes into view.

The Leonids. The Leonid shower this month will be eagerly awaited by all meteor observers, since there is a chance that it will be really spectacular. It should begin on November 15, and end on November 17. It will be at its best in the early hours of the mornings.

The Leonids are erratic and unpredictable. For many centuries they gave splendid displays every 33 years; in 1799, 1833 and 1866 it was said that meteors dropped 'like snowflakes'. In the interim periods, the activity was much less marked, though numbers of Leonids were seen every November. Then, between 1866 and 1899, the main shower was perturbed by Jupiter, so that it missed the Earth and the anticipated great displays of 1899 and 1933 did not materialize.

However, the Leonids have been showing signs of a revival of late. Activity was quite marked in the early 1960's, and the 1964 shower is estimated to have had an hourly rate of about 50 meteors, though observations were badly hampered by cloud. In 1965 the full moon will be within a degree or two of the radiant at peak activity, which will make things very difficult, but November 1966 may be a different matter. The Moon will be conveniently out of the way, and we are back with the old 33-year period.

It would be highly over-optimistic to hope for a return of the great showers of the past. However, the Leonids may well make a brave show, particularly as their meteors enter the Earth's atmosphere almost 'head-on' and are usually brilliant. There is every reason for making a special effort to observe them, both visually and photographically.

It is with these uncertain showers that amateur workers, even if inexperienced, can make a valuable contribution. The main essential is to judge the numbers of meteors seen, which is, in effect, a mere matter of counting and timing. In 1964 a television appeal for help produced excellent results (even if largely negatived in the end by widespread cloud), and it is to be hoped that the 1966 Leonids will be given the attention that they undoubtedly

deserve. Results obtained by observers in the United Kingdom should be sent to the Director of the Meteor Section of the British Astronomical Association.

The constellation of Leo does not rise until about 23 hours (11 p.m.) at the time of the shower, and so no really good results can be expected before midnight. The most favourable period will be between 1 and 5 hours on November 15, 16 and 17.

The inferior planets. This month Mercury is at inferior conjunction (between Earth and Sun) on the 17th, Venus at superior conjunction (on the far side of the Sun) on the 9th. Therefore, Earth, Mercury, the Sun and Venus are roughly lined up, and neither of the inferior planets will be properly observable.

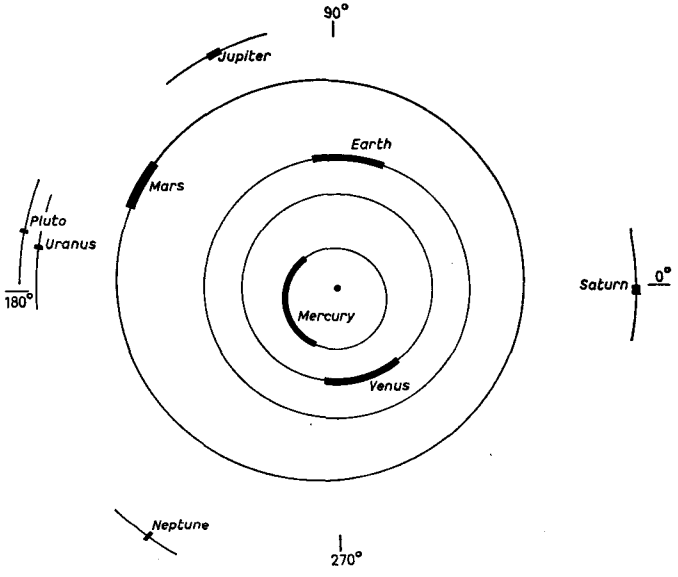
December

New Moon: December 12 *Full Moon:* December 27
Solstice: December 22

Mercury is at greatest elongation west (21 degrees, morning star) on December 4, and is then well north of the Sun, so that it may be possible to see this planet at dawn, in the south-east, a few degrees above the horizon.

Venus is an evening star, but is still close to the Sun, and moves out very slowly. By the end of the year it sets about an hour after the Sun. Venus will be a magnificent object in the evening sky throughout the spring and summer months of 1967.

Mars is in Virgo, moving direct towards the star *Spica*, which it will pass in mid-January. The planet rises at midnight at the end of



Planetary Orbits in December

the year, and the next opposition occurs in April. Mars is at aphelion (farthest from the Sun) on December 26, at a distance of 155 million miles, but the distance from the Earth is rapidly decreasing, so that the brightness is increasing, and by the end of the year the magnitude reaches +1·0.

Jupiter is moving retrograde in Cancer, and the next opposition, on January 20, will find the planet on the borders of Cancer and Gemini. The planet rises in mid-evening at the beginning of December, and the brightness continues to increase during the month (magnitude −2·0 to −2·1).

Saturn is an evening star in Pisces, and sets at midnight at the beginning of December. The Earth again passes through the ring-plane on December 18, so that we again see the south side of the rings, which are sunlit. This state of affairs will continue, with the tilt of the rings slowly increasing to a maximum of 28 degrees in 1972.

Algol. The constellation Perseus is almost at the zenith during December evenings. Its brightest star, Alpha Persei or *Mirphak*, is slightly above the second magnitude, but the most famous object in the groups is Beta, better known by its proper name of *Algol.*

Usually *Algol* shines of magnitude 2·1, and remains constant (or nearly so) for 2½ days. It then starts to fade, taking five hours to drop down to magnitude 3·3; after a brief minimum, it takes another five hours to regain its normal brightness. Behaviour of this sort is quite different from that of an ordinary variable, and in fact *Algol* is not intrinsically variable at all. It is an eclipsing binary; when the fainter component passes in front of the brighter, the magnitude falls. The fluctuations are well visible with the naked eye, and the times of minima are given in the *Handbook* of the British Astronomical Association.

Many Algol-type variables are now known. The second brightest member of the class is Lambda Tauri, where the magnitude range is from 3·3 to 4·2, and the period 3·9 days.

The end of the year. We are used to regarding December as the

twelfth month, and December 31 as marking the year's end; but it has not always been so. Originally the year began in March, and ended with the last day of February.

The first Roman calendar contained 304 days, divided into 10 months. This was much too short a 'year', and two more months were added, but the whole system had become confused, and in 44 B.C. Julius Cæsar decided to reform it. The actual work was carried out by the mathematician Sosigenes, but the calendar is always known as the Julian.

Sosigenes fixed on a year of 365 days, adding an extra day every four years to allow for the fact that the Earth moves round the Sun not in 365 days, but in 365¼. At the same time, the beginning of the year was switched from March to January, so that December became last in the list – but at that period December had only 30 days. April, June, August and October also had 30 days each; February 29, and the rest 31, so that the leap-year day was justifiably tacked on to February.

The fifth month, formerly known as Quintilis, became 'July' in Cæsar's honour. This was all very well, but when Augustus became Emperor of Rome he naturally had to have a month of his own; he took the sixth, Sextilis, which was re-named August. Unfortunately Augustus' month, with 30 days, was now shorter than Cæsar's, which had 31. This would not do at all; another day was removed from February and added to August, so that September and November were reduced to 30 days each, with October and December increased to 31. All this political manœuvring gave the final day of the year as December 31, which it has remained. The later calendar reform, instigated by Pope Gregory XIII, was merely to drop three leap-years in every 4 centuries, so making the average length of calendar year more accurate.

World calendars have been suggested now and then, but have made little progress, and it seems safe to say that in our time, at least, the end of the year will continue to be marked by the thirty-first of December.

Eclipses, 1966

In 1966 there are two eclipses, both of the Sun; there are also two penumbral eclipses of the Moon.

1. *A penumbral eclipse of the Moon* on May 4, visible in the British Isles, begins at $19^h\ 07^m$ and reaches a maximum at $21^h\ 12^m$, when the penumbral shadow covers 94 per cent of the Moon's disk. The eclipse ends at $23^h\ 17^m$. In a penumbral eclipse the change in the Moon's light is very small, and the phenomenon is unlikely to be easily seen with the naked eye.
2. *An annular eclipse of the Sun* on May 20. The path of the eclipse crosses the Sahara, the Caspian Sea, southern Russia and Siberia, but the annular phase is of very short duration. A partial eclipse will be seen in the British Isles as well as in Europe, Asia and parts of Africa. The progress of the eclipse as seen from a place in southern England is shown in the diagram on page 53; the eclipse begins at $8^h\ 23^m$, and greatest eclipse (42 per cent of the Sun being covered by the Moon) at $9^h\ 23^m$. At Edinburgh the eclipse will begin at $8^h\ 35^m$ and reaches its maximum (32 per cent) at $9^h\ 28^m$.
3. *A penumbral eclipse of the Moon* on October 29 will be visible in North America, the Pacific Ocean and Australasia. Central eclipse (98 per cent magnitude) occurs at $10^h\ 13^m$ G.M.T.
4. *A total eclipse of the Sun* on November 12 will be visible only in South America and the South Atlantic Ocean; a partial eclipse will be seen in Central and South America, and in South Africa. The maximum duration of the total eclipse is nearly two minutes.

Occultations

In the course of its journey round the sky each month, the Moon passes in front of all the stars in its path, and the timing of these occultations is useful in fixing the position and motion of the Moon. The Moon's orbit is tilted at more than 5 degrees to the

ecliptic, but it is not fixed in space. It twists steadily westwards at the rate of about 20 degrees a year, a complete revolution taking 18·6 years, during which time all the stars that lie within about 6½ degrees of the ecliptic will be occulted. The occultations of any one star continue month after month until the Moon's path has twisted away from the star, but only a few of these occultations will be visible at any one place in hours of darkness.

There are only four first-magnitude stars that can be occulted by the Moon; these are *Regulus*, *Aldebaran*, *Spica* and *Antares*. In 1966, however, the Moon's path is in such a position that it passes north of all four stars, and they cannot therefore be occulted.

There are no occultations of the major planets in 1966.

Details of occultations of the planets, and of all stars down to magnitude 7·5, as well as possible occultations of stars by planets, are published in the annual *Handbook* of the British Astronomical Association.

Comets in 1966

The appearance of a bright comet is a rare event which can never be predicted in advance, because this class of object travels round the sun in an enormous orbit with a period which may well be many thousands of years. There are therefore no records of the previous appearances of these bodies, and we are unable to follow their wanderings through space. The comets of short period, on the other hand, return at regular intervals, and attract a good deal of attention. Unfortunately they are all faint objects, and are recovered and followed by photographic methods, using large telescopes. Most of these short-period comets travel in orbits which carry them out to the orbit of Jupiter, and it is this planet which is responsible for the severe perturbations which many of these comets undergo. In 1966 the following short-period comets are expected to return to perihelion:

Comet Giacobini-Zinner was discovered in 1900, and has been seen at seven returns. It has an eccentric orbit with a period of 6½ years, and an inclination of about 30 degrees. It is this comet

which is responsible for the Draconid shower of meteors on October 9, which gave such fine displays in 1933 and 1946 – the latter being one of the first meteor showers to be studied by radar methods.

Comet Neujmin (1) has a much larger orbit, going out beyond Saturn, and having a period of 17 years. It was discovered in 1913, and was seen in 1931 and 1948.

Comet Van Biesbroeck was discovered in 1954 at Yerkes Observatory on plates exposed to confirm a new minor planet; the planet did not appear, but the comet was found in its place. The period is 12·4 years, and perihelion lies well outside the orbit of Mars.

Comet Grigg-Skjellerup has a period of only 4·9 years; only Encke's comet has a shorter period than this. Discovered in 1902, and recovered in 1922, it has made 10 appearances in all, the last being in 1961.

Although not due to return until the beginning of 1967, *Comet Tuttle* will arouse some interest, as it was not seen at its last return in 1953. Discovered in 1790, this comet has a period of 13·6 years, and travels in an eccentric orbit with the high inclination of 55°; it has been seen at 8 apparitions.

Comet Schwassmann-Wachmann (1) is visible every year because it travels round the Sun in a nearly circular orbit lying entirely between the orbits of Jupiter and Saturn. It has a period of 16 years, and undergoes remarkable changes of brightness, which seem to have some connexion with solar activity. *Comet Oterma* had a similar orbit, with a period of about 5 years, before 1963, but severe perturbations by Jupiter have made the orbit larger and more eccentric, and the period is now 19 years. The perihelion distance has increased from 3·4 to 5·3 astronomical units, and as a result the comet was not seen with any certainty in 1963–4.

Meteors

Meteors ('shooting stars') may be seen on any clear moonless night, but on certain nights of the year their number increases

noticeably. This occurs when the Earth chances to intersect the orbit of a meteor swarm, which is a concentration of meteoric dust moving in an orbit around the Sun. Such an intersection can occur only at one particular time of year, but if the dust is spread out along the orbit, the resulting shower of meteors may last for several days. The word 'shower' must not be misinterpreted – only on very rare occasions have the meteors fallen so fast as to resemble snowflakes falling.

The naked-eye study of meteors is quite a laborious task, but even a casual observer, watching for, say, ten minutes on an August night, may observe a number of Perseids. If their tracks are marked on a star map, and traced backwards, a number of them will be found to intersect in a point (or a small area of the sky) which marks the radiant of the shower. This gives the direction from which the meteors have come.

The following table gives some of the more easily observed showers, with their radiants; the effect of moonlight in 1966 is indicated.

Limiting dates	*Shower*	*Maximum*	*R.A.*	*Dec.*	
Jan. 3–4	Quadrantids	Jan. 3	$15^h\ 28^m$	$+50°$	M
April 20–22	Lyrids	April 22	$18^h\ 04^m$	$+33°$	
July 27–Aug. 17	Perseids	Aug. 12	$3^h\ 04^m$	$+58°$	
Oct. 15–25	Orionids	Oct. 20–21	$6^h\ 24^m$	$+15°$	
Oct. 26–Nov. 16	Taurids	Nov. 1–7	$3^h\ 36^m$	$+14°$	M
Nov. 15–17	Leonids	Nov. 16	$10^h\ 08^m$	$+22°$	
Dec. 9–14	Geminids	Dec. 13	$7^h\ 28^m$	$+32°$	
Dec. 20–22	Ursids	Dec. 22	$14^h\ 28^m$	$+76°$	M

M=moonlight interferes

Minor Planets in 1966

Of the 1,600 planets which are listed in the catalogue, only the 'big four', Ceres, Pallas, Juno and Vesta, can reach any considerable brightness, and only the last of these, Vesta, can occasionally

be seen with the naked eye. In 1966, however, there is no opposition of Vesta, and this planet is of magnitude 6·6 when at its brightest in January.

The planet Pallas is at opposition in October in Cetus, while Ceres comes to opposition in December on the borders of Gemini and Taurus, when it reaches magnitude 6·6. There is no opposition of Juno during the year.

Some Events of 1967

ECLIPSES

In 1967 there will be four eclipses, two of the Sun and two of the Moon.

April 24 – a total eclipse of the Moon, visible in Asia and Australasia;

May 9 – a partial eclipse of the Sun, visible in North America, the Arctic, and northern Europe;

Oct. 18 – a total eclipse of the Moon, visible in Asia and Australasia;

Nov. 2 – a total eclipse of the Sun, visible only in the Antarctic and South Africa.

THE PLANETS

Mercury may be seen as an evening star at the time of eastern elongation on February 16, and as a morning star about the time of western elongation on July 30.

Venus will be an evening star for the first half of the year, reaching greatest elongation east on June 21, and inferior conjunction on August 29. It will then be a morning star, at greatest western elongation on November 9.

Mars will be at opposition on April 15 in Virgo.

Jupiter will be at opposition on January 20, and in conjunction on August 8.

Saturn will be in conjunction on March 23, and at opposition on October 2.

Uranus will be at opposition on March 13 on the borders of Leo and Virgo; *Pluto* is at opposition on March 10 in Leo.

Neptune will be at opposition on May 14 in Libra.

Vesta will be bright enough (magnitude +5·6) at opposition on May 15 to be seen with the naked eye.

Occultations of *Antares* begin again during the year.

PART TWO

Article Section

In the current *Yearbook* we have attempted to keep up the policy of providing 'something for everybody', without overlapping the material to be found in so many recent books and periodicals. Thus while many amateurs make Newtonian reflectors, how many try their hand at Cassegrains? Yet the Cassegrain pattern has much in its favour, and this is brought out in the article by H. E. Dall, who needs no introduction to anyone even remotely concerned with optics. Henry Brinton follows with an article about telescope drives, based largely on his own extensive (and sometimes, perhaps, bitter!) experience.

Since Saturn will be of particular note in 1966, we are fortunate in having a contribution from Dr Joel Goodman, the well-known American amateur astronomer who is Recorder of the Saturn Section of the Association of Lunar and Planetary Observers – a society founded more than a decade ago, with its headquarters in New Mexico and its members to be found all over the world. And W. M. Baxter, Director of the Solar Section of the British Astronomical Association, gives his views about possible solar activity in 1966, since the Sun is now well past its minimum and should be becoming steadily more spotted again. Radio astronomy developments have been dealt with by F. W. Hyde.

University astronomy has many aspects, both research and instructional, and these are described by Iain Nicolson. Finally, and I hope not as an anti-climax, I have added my usual article about 'Recent Developments', taking the story up to June 1965 – the moment when the final page proofs of this book went to press. I hope that the mixture will prove acceptable.

The Sun in 1966

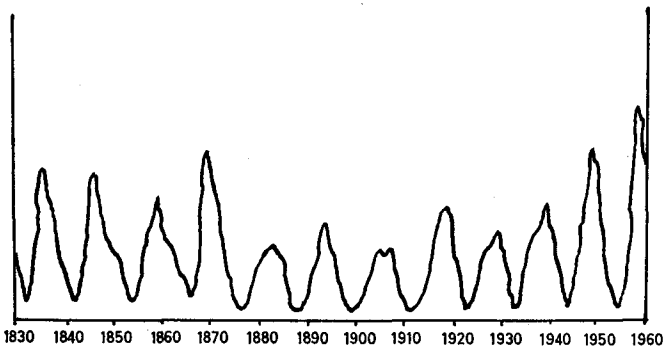
W. M. BAXTER

Prophesying what the Sun's activity will be like in 1966 is rather like fortune-telling, but this applies only to the details as we can confidently predict the general lines it will take – an increase in activity as the year proceeds.

It is generally known that the Sun's activity waxes and wanes in a regular cycle of 11 years, from minimum through maximum and back to minimum. This 11-year cycle was discovered as long ago as the middle 'eighties, by a German *amateur* astronomer, Schwabe of Dessau, who diligently observed the face of the Sun, recording sunspots from 1826 to 1851, thus coming to realize the periodicity. Since then very complete records have been kept, of course, while the years of maximum and minimum activity have actually been traced from old observations as far back as 1611, when the first views of the Sun were obtained with a telescope.

The last sunspot maximum was at the end of 1957, when day after day many spots were distributed across the face of the Sun. This was a particularly high maximum, too; in fact the highest ever recorded. Since then the activity has decreased; during 1964 very few spots were seen, and these only small ones. At the time of writing (1965) the tide has turned, and it would seem that minimum occurred about 1964 September or October; the actual date has not yet been officially declared. It will be seen that the decline has taken just under seven years, and it can be expected that the rise, now beginning, will only take about four years or so before we are again observing maximum activity.

In general, the rise in sunspot activity is more rapid than the fall, as will be seen from the diagram – which is an illustration of the variations over the past twelve cycles.



Sunspot cycle

It will be noted that the rise in each cycle is more rapid than the decline, that some maxima are higher than others and, what is of particular interest, the last maximum in 1957 was a record.

Another point of interest to the solar observer is the way the spots appear in latitudes as the cycle proceeds. They never appear near the Sun's poles, and not very frequently on the equator. With a new cycle commencing from minimum, the first sparse and small spots appear in the higher latitudes, both north and south, but rarely beyond 40 degrees. The average is about 30 degrees. Then as the Sun increases in activity the spots become more frequent, and they break out in latitudes nearer the equator until at maximum they average about 15 degrees north and south. As the cycle proceeds towards sunspot minimum the spots are less frequent, but they continue their approach to the equator, fading out at minimum at about 7 degrees latitude.

At the same time as the old cycle spots are disappearing at low latitudes, the next-cycle spots in the high latitudes are making their appearance, so that there is a certain overlap of the old and new cycles.

Although the last minimum was at about September or October 1964, a tiny spot was reported in August of that year, and a larger one in October, both in a high latitude, while spots of the old cycle were still appearing much nearer the equator.

The above gives a general picture of how things are going and, returning to the opening remarks, we can say that during 1966 the Sun should show very considerable and increasing activity, with many more and larger sunspots in medium latitudes, and this should go on until the next expected maximum in about 1969. Whether this will be a high or a low maximum we just cannot say, but we do know that the face of the Sun will be well worth watching in 1966.

Amateur astronomers will find it instructive, and indeed fascinating, to observe and record the rise in sunspot activity, particularly during 1966 and the following years; for those who have not tried it, a new field of interest lays open to them. The usual warning, which cannot be repeated often enough, must be given – on no account look direct at the Sun through a telescope, even with a dark filter on the eyepiece. The concentrated heat would certainly damage the eye, and a glass filter only gives a false sense of security as it is likely to fracture. Either use a proper solar diagonal, which is designed for the purpose or, better still, project the Sun's image on to a white card fixed behind the telescope eyepiece and suitably shaded from the direct sunlight.[1]

Sunspot counts can be made and the numbers plotted against months, to see how the activity progresses as time goes on. Any Member of the British Astronomical Association interested in this study would certainly be welcomed to the Solar Observing Section.

[1]Hints on 'Observing the Sun' were given in the *Yearbook of Astronomy 1963*

Cassegrain Reflectors for Amateurs

H. E. DALL

The Cassegrain type of reflecting telescope, with its various modifications, dominates the field in the equipment of modern professional observatories. Thus it is not surprising that the amateur who has advanced well beyond the beginner's stage is today giving increasing thought to adopting this type for his or her principal observing instrument. Aperture for aperture it will not perform any better than a Newtonian of equal optical quality, but obviously it must have worth-while advantages, or it would not be so much used in the major observatories.

Advantages. Principally, these arise from the reduction in length and weight, coupled with a reasonably long focus at the final image where the eyepiece, camera, spectroscope or electronic equipment is placed. The size of the observatory is thus minimized.

Historical. The proposal to replace the Newtonian 'flat' with a convex second mirror in about the same position was made by M. Cassegrain only three years after the Newtonian was described in 1669. The Gregorian preceded the Newtonian by a few years. This type has a concave second mirror, placed as far beyond the primary focus as the Cassegrain secondary is placed before it.

The pure form of Cassegrain is shown in Fig. 1. The laws of reflection demand that the primary should be paraboloidal in form, like that of the Newtonian or Gregorian, and the secondary should be hyperboloidal, one focus of the hyperboloid coinciding with the primary focus and the other located at the eyepiece. As the primary focus is behind the secondary, it is a virtual or inaccessible focus.

There seems to be no record of any successful use of the Casse-

grain system until well into the nineteenth century, although the Gregorian form was much exploited a century earlier. The reason is undoubtedly to be found in the difficulty of both figuring and testing the small convex hyperboloid. The Gregorian ellipsoidal secondary, which has two accessible foci, is relatively easy to test and figure. Moreover, the Gregorian gives an erect image, which, in spite of the extra length, appealed from its combination of terrestrial with astronomical use.

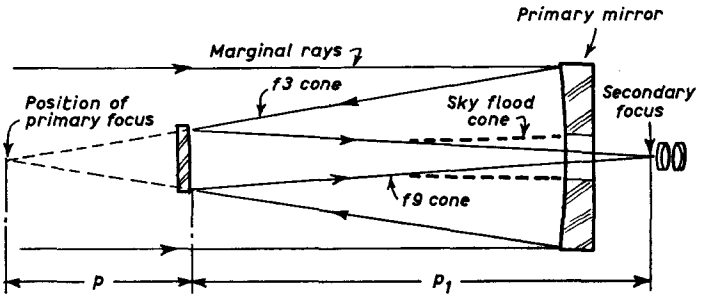


Fig. 1

The vogue of the achromatic refractor can be said to have ousted both the Gregorian and the unwieldy, long, Keplerian type of non-achromatic refractor. Although the Gregorian was less than half the length of an achromatic refractor of equal aperture, it gave a dim image by comparison, due to the poor reflective power of the speculum metal mirrors, and also to the inferiority of figuring and the sky-flooding troubles to which the Gregorian is prone. Thus during most of the nineteenth century the achromatic refractor and the Newtonian reflector were the predominant tools of both amateur and professional.

With the advent of the silver-on-glass process, the light-grasp of reflectors began to compare with that of refractors. Most amateurs favoured the cheapness and simplicity of Newtonians for apertures of 6 inches and upward, and these became the predominant type, which they remain today.

By the end of the last century, the Cassegrain form was beginning to appeal to the professional astronomer on the grounds already mentioned: that is to say, the possibility of packing a large-aperture instrument into a small observatory, yet with a workably long focus and an eyepiece available from ground-level instead of from a great height. Very few amateurs had tackled Cassegrains at this time, but they have noted the success of the professional, and desire some of the same advantages.

Referring to Fig. 1, which shows the normal or pure Cassegrain, the action of the convex secondary is exactly analogous to that of a perfectly achromatic Barlow lens, in being placed *inside* the focal plane of the primary and reducing the angle of convergence of the primary conical beam by a substantial amount. The factor of reduction of this angle is in fact equal to the magnification of the focal image compared with that of the primary image.

Fig. 1 is shown with a primary cone of f/3, with the secondary placed one-third of the focal length from the plane of the primary focus, and the final cone three times narrower than the primary cone. A telescope made to this specification (which approximates to that of a number of large modern observatory Cassegrains) would have a final focal length nine times the aperture, and a distance p_1 from the secondary to the final focus equal to the focus of the primary.

For several reasons, this is *not* a specification that the amateur is advised to adopt. First, the amateur should aim at 'diffraction limited' optics, which means figuring the curves of primary and secondary to better than one-quarter wave, or preferably one-eighth wave accuracy. This accuracy of figuring is very much more difficult with an f/3 primary than with even an f/4 primary. It is many times more difficult than one of f/5. Secondly, the diameter of the secondary of Fig. 1 needs to be more than one-third the diameter of the primary, thus involving an excessively large central obstruction, which not only wastes light but also reduces the quality and contrast in the detail of the image seen in the eye-piece.

Both these disadvantages of the f/3 type instrument are tolerated in the giant Cassegrains in the interest of size reduction,

because diffraction-limited optics are rare and exceptional, and unsteady atmosphere sets a more ponderous limit. These large instruments have a prime duty of spectroscopic and photometric work, for which light-grasp is more important than critical defining power. The amateur is thus strongly advised to adopt f/4 to f/5 for his Cassegrain, and to make the secondary not larger than one-quarter the diameter of the primary – preferably one-fifth. The length of the tube will not need to be extended more than an inch or two beyond the secondary, this representing a useful saving in size compared with an average Newtonian. This also allows a lighter stand, and a smaller observatory or run-off shed, although not noticeably smaller than for an f/5 Newtonian. However, an f/5 Newtonian has to contend with difficulties absent with the Cassegrain, e.g. obtaining a Barlow lens of requisite quality to deal with an f/5 cone and to give enough power range to permit high powers without using uncomfortably small eyepieces.

A chapter in Ingalls' classic *Amateur Telescope Making* is headed 'How to Make a Cassegrain, and Why Not To'. I strongly suspect that the author of the chapter did not give sufficient attention to sky-flooding.

Sky-Flooding. This is one important disadvantage of Cassegrain (and Gregorian) telescopes, arising from the fact that the eyepiece faces the sky, yet should deal only with light coming from the secondary mirror. It is of no great importance when observing objects in dark night skies, but is serious if the sky is moonlit or if Venus or Mercury is to be observed in twilight or daylight, or indeed for any daylight views.

Many Cassegrain telescopes have been built without provision for the elimination of sky-flooding, and no doubt this has resulted in disappointment with the performance under light-sky conditions. A milky, flooded image is anathema to the experienced observer. Three methods of eliminating the unwanted light are possible. One is the fitting of a conical baffle shield projecting up-tube from the primary, as shown dotted in Fig. 1. The geometry necessary for a particular telescope can be set out on a drawing-board, but it will be found to result in considerable increased

central obstruction if the whole required field is to be free from this trouble. A second method is that adopted in old Gregorians, in which every eyepiece cap is fitted with a tiny aperture, placed and sized to isolate the Ramsden disk or eye-beam. For several reasons this is a most unsatisfactory method. The most efficient elimination is shown in Fig. 3, in which an erecting or transfer lens is used. The method is discussed in detail later.

Primary perforation. Most Cassegrains use a perforated primary, which is another factor making them more time-consuming to build than Newtonians. The perforation may be avoided by the use of a prism or flat to divert the final beam from the optical axis to the side, preferably near to, or even passing through a hollow declination axis (see Fig. 2). This will result in convenient viewing

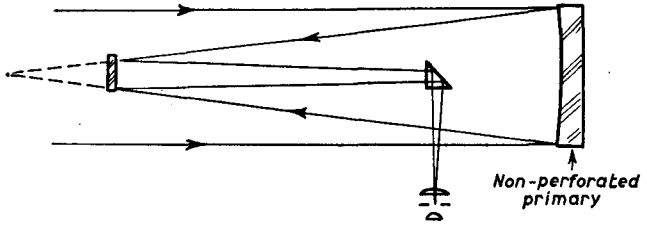


Fig. 2

under conditions of an almost fixed eyepiece, and a near-horizontal view for objects at the zenith. The standard Cassegrain with perforated mirror is certainly not convenient for zenith viewing; neither is a refractor, unless a star-diagonal is used. In British latitudes, however, objects on or near the ecliptic can be viewed in reasonable comfort without a diagonal, especially if an observing chair and a suitable head-rest is used. Some observers (perhaps those familiar with refractors) find greater satisfaction in the direct view. This agrees with the usual direction of the finder, which should be located as close to the main eyepiece as possible. The use of a star-diagonal involves some light loss and a lateral inversion of the image, confusing even to an experienced observer.

A pentagonal prism avoids the lateral inversion, but at a cost of more than double the light loss.

The design of Fig. 2 was used by J. Nasmyth, the famous engineer and selenographer, over a century ago. It suffers less from sky-flooding than the standard Cassegrain, because the eyepiece points to the sky only via the prism; nevertheless, the prism also shows the sky surrounding the secondary.

Cassegrain Coudé. If the design of Fig. 2 has the prism or flat placed at the intersection of the declination axis and a hollow polar axis, the beam can be directed down the latter, to emerge at a completely fixed position eyepiece, described in large observatory instruments as the Coudé focus (often more than f/20), so that large spectroscopes can be located conveniently.

Modified Cassegrain Forms. The pure form of Fig. 1 demands a paraboloidal primary mirror and a hyperboloidal secondary. A modification which is very much simpler to make, because of the relative ease of figuring and testing the surfaces, is known as the Dall-Kirkham. It uses an ellipsoidal primary and a simple spherical secondary. The eccentricity of the ellipse depends on the values adopted for p and p_1 (Fig. 1). For the proportions adopted for most amateur-built Cassegrains, the eccentricity lies between 0·87 and 0·90, resulting in a primary with only about 80 per cent of the correction of a paraboloid. The experienced amateur should have no difficulty in figuring an f/4 ellipsoid to the diffraction limit, expecially if a null test is used by placing the pinhole (or its equivalent) at one focus of the ellipse and the knife-edge at the other. The focus farthest from the primary will be distant some 8 to 10 focal lengths, which may need a long corridor or an outside venture.

The normal polishing operation on the secondary will generally produce an accurate sphere, but it should be checked. One method is to apply a fringe test against a concave of the same radius, e.g. the tool. Another is to grind and rough-polish the back of the secondary (made from fairly striæ-free plate glass) to a concave curve of about equal radius to the front. This curve can easily be checked for sphericity, and the convex sphere of the secondary is

tested exactly as a concave curve from the back, with no optical interference from the back curve. There is no space in this short article to give all working details to produce a Dall-Kirkham Cassegrain; for those who are interested, there is an article in *Sky and Telescope* for 1962 January. However, as a sample, the specification of a convenient design for a 10-inch f/4 Dall-Kirkham would be as follows:

10 inches, primary mirror, radius 80 inches.
Secondary, radius 20 inches, diameter 2¼ inches full.
Intercept p = 8 inches. p_1 = 40 inches, giving a ×5 focal image of 200 inches focus, f/20.
Separation of mirrors 32 inches.
Eccentricity of primary 0·870 = 77 per cent. of parabolic.
For null testing, near focus 42·6 inches, and remote focus 325 inches from mirror vertex.

Convertible Types. It is naturally more trouble to build a telescope that can be converted into a Newtonian, Cassegrain or Gregorian, and it is generally found that the user keeps to the type which, with a little thought, he could have concentrated upon from the outset. Hence I tend to look with disfavour on convertibles, and a non-convertible is obviously much easier to build. For example: with a convertible Newtonian/Cassegrain, the primary must be a full paraboloid to suit Newtonian use; also, the secondary must be hyperboloidal. The latter can be tested through the back, as described earlier, but it will not be a null test. Null tests are, of course, quite possible to organize if the equipment is available. The Hindle test uses a large sphere centred on one focus of the hyperboloid. Alternatively, the autocollimator method, using a full-sized flat, can be used to test the whole set-up. Again, a null test on a star is always possible, weather permitting, with the complete instrument.

Erect-Image Cassegrains. It cannot be too highly stressed that neglect of attention to sky-flooding will result in disappointing views. As mentioned earlier, the most efficient way of eliminating this trouble is to use an erecting lens. A sky-flood stop is placed at

a conjugate of this lens, where the image of the primary or secondary is formed. The erecting lens itself, as shown in Fig. 3, is

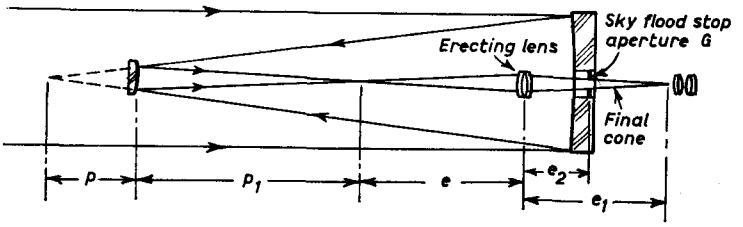


Fig. 3

placed between the secondary and the eyepiece – even a third of the way up-tube from the primary, being supported on a tube passing through the primary perforation. Much elasticity of design is possible, and in my chief observing instrument, of 15½-inch aperture, I make use of a battery of four erectors of various foci, giving final foci between f/12 and f/200. With the former, and a low-power eyepiece, the whole lunar disk is accepted into the field of view. Convertibility into Newtonian for the benefit of low-power, wide fields thus becomes unnecessary. The erecting lens must naturally be of good quality, corrected for colour, spherical aberration, and coma (an error affecting only outfield images) for the conjugates for which it is to be used.

Again there is some elasticity, because an erector designed to magnify ×2 will give good performance over a range ×1·5 to ×3. If an extra-long focus is required, e.g. f/80 for lunar or planetary photography, an ordinary well-corrected achromatic such as a binocular objective will be satisfactory. On the other hand, if a ×1 erector is required, it will be necessary to use a pair of distance-corrected objectives, or alternatively a Loups type triplet lens consisting of a double-convex crown element between two dense flint elements. This type of lens is normally designed for use at ×1. The use of one or more erecting lenses, each with its sky-flood stop bored to permit *only* the image of the primary mirror to pass, not only eliminates sky-flooding completely, but, by using a small-iris

diaphragm as a stop, the whole aperture of the telescope is under easy control if required, by a lever accessible from the eyepiece.

Other advantages accrue from the use of an erecting lens:

(1) It permits relatively small central obstruction, while effectively blocking sky-light.
(2) By varying the erector-eyepiece separation, one eyepiece can be used for a range of powers.
(3) Giving a narrow final cone, simple Huyghenian eyepieces are entirely satisfactory.
(4) A natural erect image permits good terrestrial viewing, and makes for much greater ease in following a moving object, e.g. a satellite in orbit.

If the 10-inch f/4 Dall-Kirkham Cassegrain given in the earlier example is fitted with an erecting lens, it will modify the specification to some extent. If an erector of 5-inch focus ($1\frac{1}{4}$ to $1\frac{1}{2}$ inches diameter) is used to give the same final focus of 200 inches, and is operated at $\times 2$, the specification becomes (see Fig. 3):

$p = 8$ inches, $p_1 = 20$ inches.
Radius of secondary 26·7 inches. $e = 7{\cdot}5$ inches, $e_1 = 15$ inches, $e_2 = 6$ inches, and $G = 0{\cdot}45$ inches (bore of sky-flood stop).

The quality and corrections of the erecting lens are more important if wide fields of low power are required, e.g. for variable star magnitude estimates. A good erector will not introduce perceptible colour fringes, and the erector system enables the central obstruction to be cut down to as little as 1/7 of the primary diameter if wide fields are *not* demanded. Thus for high-resolution planetary work, the harmful effects of diffraction due to central obstruction can be removed, and if the telescope tube is closed with an optical window, a practice currently becoming more common, the secondary may be attached thereto, thus eliminating a further source of diffraction trouble.

Schmidt-Cassegrains. If critically sharp (i.e. definition limited only by diffraction) fields of 1° or so are required, the Schmidt and

Cassegrain systems can be combined, and will give a combination of advantages, e.g. the primary a simple sphere and as short in focus as f/2·5. A system due to Linfoot uses an ellipsoidal secondary attached to the corrector plate. The latter becomes the crucial component, and needs many fringes of difficult figuring (against the primary) for short foci.

Maksutov-Cassegrains. As the Cassegrain system is well adapted to deal with short-focus primaries, it is natural that most Maksutov telescopes are of Cassegrain form. Spherical curves throughout are suitable if the primary is of focus longer than f/4. If shorter, some figuring is necessary to achieve the diffraction limit. It will not give the large diffraction-limited fields of the Schmidt-Cassegrain, but gives an ample field for amateur requirements. The deep optical glass meniscus can be an expensive item, and tends to restrict the use of the system.

Ritchey-Chretien Cassegrains. This design has rarely been adopted by amateurs because it demands the difficult figuring of hyperbolæ for both primary and secondary. It has considerably less coma than the pure Cassegrain, which in turn has less coma than the simpler Dall-Kirkham. The presence of coma is of little importance for visual observation, but for photography of deep-space objects such as clusters it becomes quite important – hence the choice of the Ritchey-Chretien Cassegrain for some modern large observatory telescopes, such as the 84-inch at Kitt Peak in the U.S.A.

Telescope Drives

HENRY BRINTON

Among the many irritating tricks by which celestial bodies seek to avoid observation by the amateur astronomer, when he first takes up his hobby, is their apparent movement – which quite baffles the observer equipped with a 3-inch refractor mounted upon a wobbly altazimuth stand.

With the highest power on my own telescope (a 12-inch reflector), a star moves right across the field in a matter of twenty seconds. When giving children their first look through a real telescope, I find that letting them observe this rapid drift is a highly dramatic demonstration of the Earth's movement.

When buying a new telescope, the question of a drive presents few problems. Manufacturers offer a number of alternatives, and it is only a question of balancing cost against the required accuracy. The difficulty arises when converting an instrument which has not previously had any driving mechanism.

The first thing is to be clear of the purpose for which the drive is required. For visual observers, who do not intend to go in for photography, no great accuracy is needed. If planetary and lunar photography is intended, accuracy becomes a serious factor – though, even so, the need is less than is commonly supposed. It is only when very long exposures are needed for such objects as galaxies that very great accuracy is essential.

Motive power presents no difficulty. My own telescope, which was built by Calver in 1889, was driven by weights when it came into my possession. The system was simple and satisfactory, except that at crucial moments the weights always needed winding up. Nearly all telescopes are now driven by electric motors of one sort or another. Motors of all types and sizes are readily available,

many of them for very small sums of money. The main problem is one of reduction gear.

Since the telescope has to turn once in just under 24 hours, the drive has to be very slow indeed. A large reduction is provided by the usual practice of worm and wheel, with the latter on the main axis. This, however, still needs the worm to turn very slowly indeed, whereas most available motors have a speed up to 1,500 rpm. This calls for a total reduction of the order of two million to one.

Gearing is very expensive to make, and calls for skill and patience to make for oneself. There used to be ex-government bomb-sights on the market very cheaply, which contained large and accurate reduction trains; but these are now hard to come by. Series of radio tuning slow-motion drives have also been used.

If the drive is for convenience only, a simple way out of the difficulty is to use windscreen-wiper motors. These are sturdy, cheap and need a minimum of extra reduction. At break-up yards they can be bought for a few shillings. They have the added attraction of being battery-driven, or driven from a simple charger, thereby avoding the risk involved in having mains voltage in a damp garden. With either source of power, they will give a surprisingly steady drive. Fitted with a rheostat, they will be accurate enough, over short periods, for planetary photography.

For greater accuracy, a synchronous motor is generally used. At times of heavy load, the frequency may vary by perhaps 2 per cent, and the generating station is apt to make up the difference late at night, just when one is using the telescope. Otherwise, a synchronous motor is accurate enough for most purposes. Even with the normal variations of frequency, it will serve for planetary work – for anything, indeed, except very long exposures.

Synchronous motors with reduction can be bought cheaply, with powers of a few inch/ounces. There are, of course, clock motors, and switch motors which will serve excellently if the power required is small enough. Unfortunately the power available is marginal, depending upon how finely balanced the telescope is. A typical switch motor will give about 6 inch/ounces at 4 rpm.

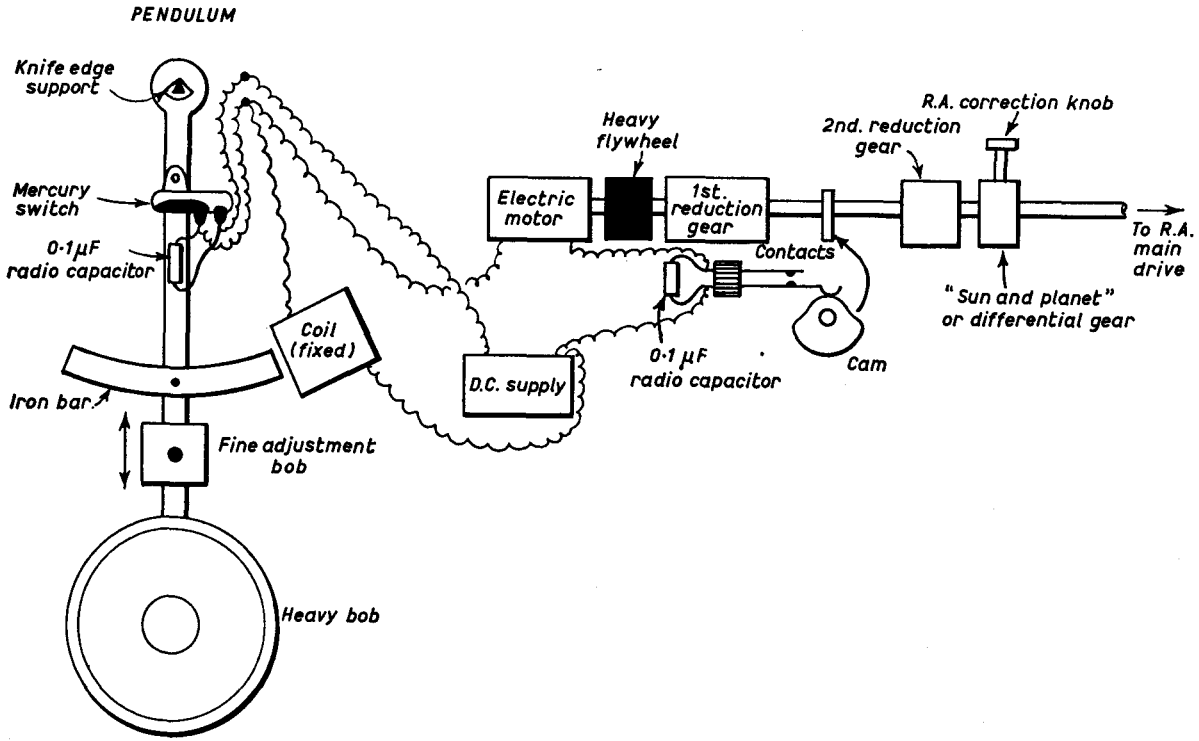
Another method of controlling the drive speed is with the Gerrish drive. This system provides a free-swinging pendulum to give continuous corrections to the motor speed. A cam is fitted to a suitable point on the reduction gearing from the electric motor so that it will close a set of contact points at intervals of, say, once a second. The pendulum is fitted with a second set of points, in series with those on the cam, and is of a length which will produce a period in harmony with the required speed of the cam-shaft.

The motor is thus fed with pulses of power, and a heavy fly-wheel is fitted to the motor to smooth out the fluctuations. The motor is set to drive too fast; the second switch on the pendulum, however, will prevent the pulse from being fed to the motor until the pendulum has reached the angle at which the switch on it closes, and will thus hold the drive to exactly the required speed. The pendulum itself can be adjusted for fractional corrections by shortening or lengthening the distance of the bob from the pivot.

John Smith has provided a simple lay-out for a Gerrish drive, as shown in the accompanying figure. The pendulum is fitted with a mercury switch, and is maintained by the use of a stationary solenoid acting on a curved iron bar attached to the pendulum rod. A slight 'slopping' of the mercury keeps the current flowing slightly longer on the return than on the up-swing, and so imparts the necessary impulse. In this system the cam-shaft should rotate once every two seconds if a seconds pendulum is used. The mercury switch closes on the left-hand stroke only.

A rather more refined version, also suggested by John Smith, makes use of an artificial gravity for fine adjustments of the pendulum, which is fitted with an iron block at the bottom. Underneath is fitted a small adjustable solenoid to control the rate of the swing. A further refinement is to provide buttons, one of which will cut out the current altogether, while the other will by-pass the contacts and provide a continuous current. These will permit movements of the image in small steps.

Another problem which has to be overcome is the slow-motion adjustment in right ascension. A simple and inexpensive way of dealing with this is to make the main drive through a drill-chuck


PENDULUM
Knife edge support
Mercury switch
0·1 μF radio capacitor
Coil (fixed)
Iron bar
Fine adjustment bob
Heavy bob
D.C. supply
Electric motor
Heavy flywheel
1st. reduction gear
2nd. reduction gear
R.A. correction knob
Contacts
0·1 μF radio capacitor
Cam
"Sun and planet" or differential gear
To R.A. main drive

reduction gear, with a reduction of 4 to 1. For normal drive, the gear-case is locked. For slow-motion, the casing can be driven by a secondary reversing motor, for which purpose almost any motor with a large reduction will serve. A windscreen-wiper motor is excellent for the purpose. The reversing switch is fixed near the eyepiece, or held on a long flex in the hand.

A further method of securing the slow-motion and, at the same time, providing a flexible control of the main drive speed is to use one of the frequency-generating devices now obtainable, complete with a reversing switch. The range of frequencies available is sufficient to adjust the image by increasing the frequency to maximum for forward adjustment, and to use the reverse for backward movement. The frequency control, which is kept at a predetermined norm for following a star, can also be adjusted slightly to match the movement in right ascension of the Moon or a comet.

There has been space here to mention only a very few of the points about drives in what might be called the 'middle ranges'. My own reflector is still driven through the ancient and ponderous brass governor designed by Calver, though the motive power is now a wiper-motor. At the other extreme, professional telescopes are controlled by electronic devices beyond the range of the amateur. (Not, perhaps, the more versatile amateur, but those in such a class will not need instructions which are condensed into a single paragraph!)

As with so much else, where telescopes are concerned, each instrument has to be considered on its own terms. Popular though astronomy has become, we have not yet reached the era of the mass-produced telescope of larger size than a toy.

Introduction to Saturn

PATRICK MOORE

The year 1966 will be of particular interest to observers of Saturn. The rings will be edge-on to us, a state of affairs which has not occurred since 1951, and the planet will have an unfamiliar aspect, less beautiful than usual but perhaps even more fascinating. The forthcoming events are treated in full in the article by Dr Joel Goodman, Recorder of the Saturn Section of the Association of Lunar and Planetary Observers (the leading American amateur organization), but a few remarks may be useful by way of introduction.

Saturn, the outermost of the planets known in ancient times, is very remote. Its mean distance from the Sun is 886,000,000 miles, and its revolution period amounts to 29½ years. It is a giant, with an equatorial diameter of 75,100 miles; even so, it is considerably smaller than Jupiter as well as being farther away, so that in our skies it does not shine nearly so brightly. At its best, it may outshine all the stars visible from Britain apart from Sirius, but this depends upon the rings being fully displayed. This year, with the rings closed, Saturn will not equal Vega, Capella or Arcturus.

For some years now Saturn has been well south of the celestial equator, so that British and United States observers have been working under difficulties. By now, however, things have improved considerably. Saturn has not returned to the northern sky, but its altitude is growing steadily, and during 1966 it will be tolerably high up. There should be no difficulty in recognizing it, mainly because there are no first-magnitude stars anywhere near it. The chart on page 66 shows its position at the time of opposition. In colour it is somewhat yellowish, though the casual observer will probably regard it as white.

Any small telescope will show that Saturn is not a perfect globe. It is decidedly flattened, and its polar diameter is less than 70,000 miles. This is a result of its quick axial rotation, which is not much over 10¼ hours – longer than Jupiter's, but still short by terrestrial standards. Unfortunately, our knowledge of the various rotation zones is by no means as complete as we would like.

With Jupiter there is no difficulty in measuring the rotation period very accurately. The Jovian disk is crowded with detail; there are the famous belts, together with spots, wisps and festoons, to say nothing of the famous Great Red Spot (which has been remarkably conspicuous lately, and is strongly coloured). All that the observer has to do is to time the moments when various features come 'to transit' – that is to say, cross the planet's central meridian. The appropriate longitude of the feature may then be worked out, and successive transits will yield an accurate value for the rotation period. Since Jupiter has a gaseous surface, it does not rotate as a solid body would do. The equatorial zone has a period of about 9 hours 50 minutes, and the rest of the planet about five minutes longer, though special features have periods of their own.

Saturn is basically the same kind of world as Jupiter, with a gaseous surface, but the observational problems are much greater. The main belts are easy enough to see, but they usually appear more or less featureless, and spots are depressingly rare. All in all, there are very few details definite enough to be used for transit-taking. It is certain that the rotation period is longer near the poles than near the equator – perhaps by twenty minutes or so – but direct observation of the disk by instruments of amateur size has not told us a great deal. With Jupiter, on the other hand, most of our information has been gained from amateur work carried out during the past seventy years or so.

Spots on Saturn are worthy of close attention whenever they appear. The most famous case is that of the white spot of 1933, discovered by W. T. Hay, a British amateur better known to the general public as Will Hay, the stage and screen comedian. For a few weeks the spot was quite prominent; I remember seeing it well with the 3-inch refractor which I owned at the time. Yet it did

not last for long, and faded completely away. Dim white patches have been seen near the planet's equator since then, but have been in no way comparable. I found one myself a few years ago; it was confirmed by observers in Britain and the United States, but to my intense annoyance it disappeared before it had yielded anything of value!

The belts, unlike those of Jupiter, appear sensibly curved. Their general aspect is often confused, so far as the inexperienced observer is concerned, by the rings and ring-shadows, though a little practice makes it easy enough to sort out which is which. Colours have been reported often enough, ranging from rich yellows to elusive greens, but there is nothing anything like so definite as, say, the Red Spot on Jupiter.

Saturn has the distinction of being the least dense of all the planets. It has an overall density less than that of water, but even so its great size means that it is of high mass, and its escape velocity is as much as 22 miles per second. Its outer parts are made up largely of hydrogen, with methane (a hydrogen compound) very prominent in its spectrum. Its internal constitution is a matter for debate. On an old theory due to R. Wildt, there may be a rocky core, overlaid with an ice-layer which is in turn overlaid by the gaseous atmosphere; another model suggests that Saturn is made up largely of hydrogen all the way through its globe, though near the centre the pressure is so great that the hydrogen behaves in a somewhat un-gaslike fashion. There is nothing to be said now for the theory that Saturn, like the other giant planets, is a miniature sun at high temperature. We may be sure that the giants are intensely cold, and life, at least of the kind we know, is quite out of the question.

The rings were first seen by Galileo three and a half centuries ago, but it was left to Christiaan Huygens, in 1655, to discover their true form. Strictly speaking there are three rings, two (A and B) bright, and the third (C, or the Crêpe Ring) dusky. No solid or liquid sheets could exist in such a region, as the gravitational pull of Saturn would result in prompt disruption. The rings are made up of large numbers of small particles, moving round the planet

in the manner of dwarf moons. They may have been produced by the break-up of a former satellite which wandered too close to Saturn; they may be due to material which never condensed into a proper satellite – it is wellnigh impossible to be sure. Since the ring-particles are obviously reflective, it has been suggested that they are made up of ices, or are at least covered with ices of some sort.

The bright rings, A and B, are separated by the famous Cassini Division, which is simply a gap due to the gravitational influence of Saturn's satellites – particularly the innermost, Mimas. Other Divisions have been reported, one of which, Encke's Division in Ring A, has been drawn on numerous occasions, but some astronomers hold that these minor divisions are more in the nature of 'ripples' than gaps. Since none of the ring divisions will be on view in 1966, no more need be said about them here, and neither need I discuss the hypothetical, dusky Ring D, outside the main ring-system. Ring D has been reported many times since 1909, but its existence is still unproved. I admit that I have often looked for it, with very large telescopes, without success.

The rings have been described as 'the flattest things in the Solar System'. Though the full diameter of the system approaches 170,000 miles, the thickness can hardly be more than 10 miles, which explains why the rings are so elusive when edgewise-on to us. In passing, let us note that the ring-system is circular, as shown in a 'bird's-eye view'. From Earth, we always see it at an angle.

Saturn has nine satellites (a tenth, reported by Pickering in 1904 and named Themis, has never been confirmed, and is probably non-existent). Of these, only Titan is visible in very small telescopes, but several more are within the range of moderate instruments.

The two innermost satellites, Mimas and Enceladus, cannot be as much as 400 miles in diameter, and are difficult objects, though a 6-inch refractor will show them under good conditions. Numbers 3 and 4, Tethys and Dione, are visible with a 4-inch refractor, and are rather larger; Dione is considerably the more massive of the

two, though most observers consider it slightly the fainter. Beyond comes Rhea, visible with a 3-inch refractor, and probably at least 900 miles across – though precise values are difficult to obtain, and different authorities give different figures.

The sixth satellite, Titan, is a large body. It seems to be as large as the planet Mercury, and its diameter is given as between 2,900 and 3,500 miles, probably closer to the second figure. Large telescopes can show vague details on its surface, and it has, moreover, the distinction of being the only satellite in the Solar System known to have an atmosphere. In 1944 G. P. Kuiper detected a methane mantle, since fully confirmed. Titan is visible with a 2-inch telescope, and 1966 will be a good year for following it. It is also the only satellite whose transits, eclipses and occultations may be followed with amateur-sized instruments.

Beyond Titan comes Hyperion, only about 200 miles across, and very faint; I never find it an easy object in my 12½-inch reflector. The best chances of identifying it come when it is in conjunction with Titan. At a considerably greater distance lies Iapetus, discovered as long ago as 1671; here, too the diameter is uncertain, and is given variously as from 750 to 2,000 miles – perhaps 1,300 would be a reasonable guess. At any rate, it is reasonably prominent when west of Saturn, and may then become brighter than Rhea. It is not nearly so bright when east of Saturn, so that clearly it has a surface of unequal reflecting power. There can be little doubt that it spins on its axis in the same time that it takes to revolve round Saturn, i.e. 79 days. All the major satellites of the planets have 'captured rotations' of this sort, due to tidal effects over the ages.

Finally, at the edge of the Saturnian system, comes Phœbe, first seen by W. H. Pickering in 1898. It lies about eight million miles from Saturn, and cannot be much more than 150 miles across, so that it is beyond the range of moderate telescopes. It has a retrograde or 'wrong-way' movement, and a high orbital inclination, so that it may possibly be a captured asteroid instead of an ordinary satellite.

Generally, the disk markings and the satellites of Saturn are

neglected in favour of the spectacular rings. In 1966 the situation will be abnormal. There will be much of interest to watch in connexion with the rings, as Dr Goodman explains in his article, but the coming year also gives a fine opportunity for those who are anxious to study Saturn in all its aspects.

The Edgewise Presentation of Saturn's Rings

JOEL W. GOODMAN

(Recorder of the Saturn Section of the Association of Lunar and Planetary Observers, U.S.A.)

I. Geometrical Relationships of the Ring-Plane to the Plane of the Earth's Orbit

As Saturn proceeds about the Sun, a cycle which consumes 29·5 years, its ring system passes through a succession of positions as seen from the Earth. During each cycle the plane of the rings twice intersects the plane of the Earth's orbit. These periods of intersection recur at successive intervals of 13·75 and 15·75 years. During the shorter interval the southern surface of the rings is exposed and the planet passes through perihelion, while during the longer interval it is the northern surface which we see and Saturn passes through aphelion. The inequity of the two time intervals is attributable to the greater mean velocity of the planet when near perihelion than when near aphelion.

The geometric requirements for an edgewise presentation of the rings can perhaps be more readily visualized by reference to Fig. 1, although the clarity inherent in a three dimensional model is unfortunately lacking. For simplicity, the orbits of the Earth and Saturn have been represented as circular and coplanar and have not been drawn to scale. While neither of the first two approximations is strictly accurate, they in no respect invalidate the discussion to follow.

The broken lines AD and BC are projections of the ring-plane which fall tangent to the Earth's orbit, EFGH. Hence, when Saturn lies within the arcs AB or CD the ring-plane intersects the orbit

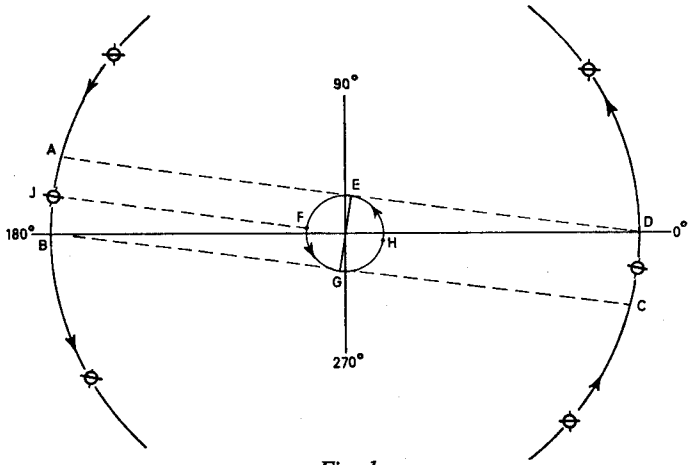


Fig. 1

of the Earth. Since Saturn's distance from the Sun is 9·54 astronomical units, each arc subtends an angle of about 12 degrees at the Sun and they happen presently to lie between about heliocentric longitudes 168°–180° and 348°–360°. The orbital positions of these arcs are subject to the effects of precession, which, however, in the case of Saturn are much more gradual than in that of the Earth.

Travelling at mean velocity, Saturn requires approximately 360 days to traverse 12° of its orbit. During the 360 days periods when the planet is between A and B or C and D, whenever the line joining it and the Earth becomes parallel to the tangents AD and BC (the ring-plane) the rings will be presented edge-on. For example, an edgewise presentation would occur when the Earth is at F and Saturn is at J.

During the intervals when the ring-plane intersects the Earth's orbit it must pass once and only once through the Sun, but the Earth, by virtue of its greater orbital velocity, can pass either once or three times through the ring-plane. For purposes of illustration, let us consider the following situations.

In the former instance, if when Saturn reaches C the Earth

happens to be between G and H or H and E (the side of its orbit which is closest to Saturn), the Earth's motion, which is more than three times that of Saturn, will keep it ahead of the advancing ring-plane. The line joining the two planets will not become parallel to the ring-plane until the Earth passes the point E and is on the far side of its orbit. It will be unable to overtake the ring-plane upon returning to the nearside of its orbit before Saturn passes the point D and consequently only a single passage of the Earth through the ring-plane will occur.

If, on the other hand, the orientation of the two planets happens to be such that the Earth is between E and F or F and G when Saturn reaches C, then there will be one passage through the ring-plane before the Earth reaches G, a second passage when the Earth is somewhere on the arc GHE and a third when it is between E and F shortly before Saturn reaches D.

The two situations described above represent by far the most common panoramas during periods of Earth-ring coplanarity. There appears to be a somewhat greater statistical probability for three than for a single passage, the ratio being about 53:47.

Under unusual circumstances, the Earth may enter the ring-plane twice, although there will result only a single passage across the plane. If the Earth is precisely at or a little beyond G at the time when Saturn reaches C, then the Earth will be moving almost directly towards Saturn and the ring-plane will overtake it. However, the Earth's motion will carry it ahead of the ring-plane before the latter passes through. Subsequently, the Earth will make a true passage through the plane somewhere on the far side of its orbit, but before it can again overtake Saturn the latter will have moved beyond D. Similarly, if the Earth is precisely at or only slightly beyond E when Saturn reaches C, then a passage through the ring-plane will occur when the Earth is somewhere between F and G. The earth will again overtake Saturn when the latter is very near D, but since it will be moving almost directly away from the outer planet, Saturn will cross D before a passage through the plane can transpire. Thus, in each of these two situations only a single passage *through* the ring-plane occurs

although there is a second entry of the Earth *into* the plane. The exacting alignments required for these events make them very rare indeed.

Three passages of the Earth through the ring-plane will occur during 1966, when Saturn will be between heliocentric longitudes 350° and 360°. The dates of the crossings in Universal Time and the heliocentric longitude of Saturn on each of the dates, interpolated from data in the American Ephemeris and Nautical Almanac, are as follows:

Date	*Heliocentric Longitude*
1966 April 2	350° 37′
1966 October 29	370° 35′
1966 December 17	359° 15′

On April 2, the Earth will cross the ring-plane going south and the southern surface of the rings will become visible. The ensuing months will permit scant inspection, however, for the maximum opening, during July, will fall a bit short of 3 degrees. Thereafter, the rings will gradually close as the Earth strives to pull abreast of Saturn until, on October 29, it makes a northward passage across the ring-plane. The exposure of the northern surface of the rings will be miserly indeed, as the maximum Saturnicentric latitude of the Earth, referred to the ring-plane, will be but 0°·25 prior to the final passage of the Earth which occurs on December 17. Henceforth, the southern surface of the rings will be inclined toward the Earth for almost 14 years until Saturn moves to the arc AB of its orbit.

Referring to the diagram, the initial passage on April 2 will occur when Saturn is somewhat beyond C and the Earth is between F and G. The second passage will find Saturn rather close to D and the Earth between H and E, and on December 17 Saturn will have almost reached D and the Earth will be on the arc EF of its orbit, but much closer to E than to F.

While the Earth is involved in this series of ring-plane passages, the ring-plane will pass through the Sun on 1966 June 6 when Saturn reaches heliocentric longitude 353° 01′. Prior to that time

the northern surface of the rings will have been directly illuminated by sunlight, but subsequently the southern surface will be inclined toward the Sun.

II. Phenomena Associated with the Rings

During epochs of Earth – Sun passage across the ring-plane, the two bodies are at times on opposite sides of the plane. Their alignment will be such for two periods during 1966. Since the Earth makes a southward passage across the ring-planes on April 2, the Earth and the Sun will be on opposite sides of the plane between that date and June 6, when the Sun joins the Earth below the rings. They will again be oppositely placed between October 29, when the Earth moves north of the ring-plane, and December 17, the date of the final passage south.

During these intervals, as well as the few hours when the Sun is precisely in the ring-plane, the rings may well be lost to view in small telescopes of, let us say, about 4 inches aperture or less. Theoretically, they might be expected to be invisible regardless of aperture, but the experiences of a large number of observers extending back for more than a century provide overwhelming evidence that they remain detectable in instruments of even moderate size. Thus, the only condition under which the rings are totally imperceptible is when the Earth lies exactly in their plane, a state which endures for but a few hours during each crossing.

The surface of the rings which is not receiving the direct rays of the Sun often does not appear to be uniformly illuminated but rather to possess condensations of brightness along its expanse. This effect, described often in the past, is shown in Fig. 2, which depicts Saturn as seen by Barnard in 1907 when the Earth and the Sun were north and south of the ring-plane, respectively. Two bright condensations separated by a void are shown on each side of the planet. These bright areas may vary in number and breadth and the ring has at times been described as a series of beads of light, though with smaller telescopes than the 40-inch refractor used by Barnard. The number and appearance of these spots may well be functions of aperture and seeing conditions. With smaller

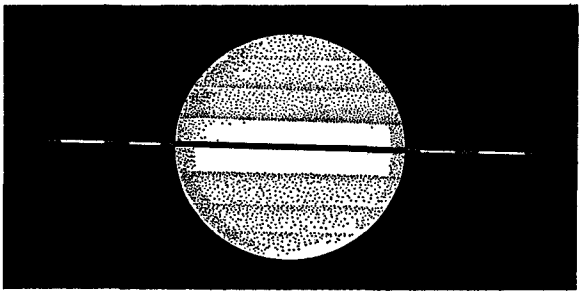


Fig. 2

telescopes, in which they may behave as point sources, and in unsteady air they may appear to sparkle or scintillate, an effect for which irradiation may most reasonably be blamed.

Various explanations have been advanced to account for the visibility of the unilluminated surface of the rings. Perhaps the most thoughtful treatment of the problem should be credited to Henry N. Russell of Princeton University in 1908 (*Astrophysical J. 27*:230). Russell calculated that the intensity of the light reflected from Saturn at the distance of the outer condensations is about 560 times terrestrial moonlight, but since Saturn would appear from the condensations as a half-illuminated rather than fully illuminated sphere, the intensity would probably be of the order of only 160 times terrestrial moonlight. From the albedo of the rings and the apparent size of the condensations, he determined that their apparent magnitude would be between 10 and 11 magnitudes fainter than Saturn, a derivation consistent with Barnard's observations. Regarding the inner condensations, he agreed with Barnard's earlier interpretation that they derive from sunlight diffusing through the sparse crêpe ring to the visible surface.

With the great variety of telescopes presently in use by planetary observers throughout the world, it will be of great interest in 1966 to define the limits of visibility and the uniformity of the ring surface which is turned away from the Sun.

Several other aspects of the nearly edgewise ring system are

worthy of note. During some previous analogous periods, the ansæ, visible as exceedingly narrow threads of light, have been considered of unequal length, with the preceding (westerly) ansæ having the greater span. In 1936, with the Earth extremely close to the ring-plane, E. M. Antoniadi, using the 33-inch Meudon refractor, estimated the ring as showing its entire length of 2·3 radii to the west, but as being about 20 per cent shorter to the east (*B.A.A.J.*, *47*:52). When the rings are but narrowly open and the Earth is at a greater elevation above their plane than the Sun, they have been remarked to assume a bluish hue, and ring A may appear brighter than ring B, quite out of character with the normal order.

III. Phenomena Associated with the Satellites

When the Earth and Sun are close to the orbital planes of Saturn's satellites, which, of course, must happen concurrently, phenomena of the type visible each apparition in the case of Jupiter's satellites can be seen. These consist of transits of satellites and their shadows across the globe of the parent body, as well as eclipses and occultations by the shadow and behind the body of Saturn, respectively. It should be understood that although the Earth and the Sun must perforce approach the orbital plane of the satellites simultaneously, eclipses and shadow transits require only that the Sun be near the plane, while satellite transits and occultations require only the proximity of the Earth to the plane.

While satellite phenomena involving Jupiter are visible each year, those involving Saturn are visible for only five successive apparitions out of every fifteen, symmetrically distributed about the passage of the Earth through the ring-plane. This can be understood when it is realized that the orbital planes of the seven inner satellites lie nearly in the plane of the equator and rings; hence their apparent inclination to the Earth is usually considerable. Since a tilt of only a few degrees to the line of sight would suffice to carry the satellites clear of the planet's globe, it is only for about two years before and two years after the edgewise position that the angle of inclination is small enough to permit the observation of satellite phenomena.

To further complicate a difficult situation, the satellites of Saturn are far more distant from the Earth than those of Jupiter, and consequently their apparent brightness is proportionately less. Therefore, observers with small telescopes will have difficulty with the phenomena of all save Titan. Shadow transits of Titan should be visible with about 3-inch telescopes under favourable conditions, as the shadow subtends an angle of about one second of arc, but it is extremely doubtful whether the satellite itself in transit could be seen with such an aperture.

Eclipses and occultations are far easier to observe than transits, but precise timings of entry of a satellite other than Titan into or exit from Saturn's shadow present grave difficulties due to their faintness. The same limitations apply to the disappearances and reappearances of satellites during occultations.

It must also be recognized that the size of the umbra of a satellite's shadow is a function of the size of the satellite, its distance from the planet and its distance from the Sun. The shadows of Saturn's outer satellites are largely penumbral. In the case of Dione, for example, which is the fourth satellite out, the penumbral contribution amounts to about 25 per cent. These factors, then, which include apparent faintness due to small size and distance from the Earth and distance from Saturn, combine to make satellite transits very difficult to observe. While shadow transits of the six innermost satellites have been reportedly seen with apertures of only about 6 inches, such performance seems incredible in light of the theoretical obstacles.

The two outermost satellites, unlike the other seven, have orbits with appreciable inclinations to the ring-plane. Phœbe, because of its extreme faintness and distance from Saturn, warrants little consideration in this discussion. Iapetus, on the other hand, is brighter than Rhea at times (near western elongation) and consequently second only to Titan in this respect. Phenomena of Iapetus are rare because of its great distance from Saturn and, more importantly, because its orbit is inclined at 14° 43′ to Saturn's equator and at 18° to the ecliptic. As a result, Saturn reaches a longitude at which the orbit of Iapetus becomes edgewise to the

Earth and Sun about two years prior to the edgewise presentation of the ring-plane. The former occurs when Saturn reaches heliocentric longitudes about 145° or 325°, and Iapetus' orbit plane is at ecliptic longitude about 141° (its ascending node) or about 321° (its descending node). Then, at some time within a period of a few weeks, Iapetus may be in conjunction with Saturn, and a transit, occultation or eclipse may occur. However, no phenomena will take place if Iapetus is near greatest elongation at the critical time, because its period is almost 80 days and the Earth will have moved out of its orbital plane before the subsequent conjunction. Opportunities come at about 15-year intervals, and carry the possibility of observing an eclipse by the rings, since they are partially open at the time.

Such an eclipse occurred in 1889 and was observed by E. E. Barnard with the 12-inch refractor at Lick Observatory (*Monthly Notices of Royal Ast. Soc., 55*:369). He found that Iapetus dimmed following passage into the shadow of the Crêpe ring and abruptly disappeared upon reaching the shadow of Ring B. Much later, these findings were applied to a consideration of the optical properties of the rings.

Upon occasion, occultations and eclipses of one satellite by another may occur but they require superb observing conditions and considerable aperture for satisfactory observation. Occultations and eclipses of another satellite by Titan or its shadow provide the most promising opportunities for modestly-equipped observers. Eclipses are less frequent than occultations, and are hence extremely rare, but a passage of Rhea through the shadow of Titan in 1921 was successfully witnessed with amateur instruments as small as 4·5 inches aperture (*B.A.A.J., 31*:271).

Thus, epochs of ring closure provide opportunities to observe unusual phenomena associated with the rings and satellites which can be seen only at such times. The period of near and exact coplanarity in 1966 is particularly favourable, since three passages of the Earth through the ring-plane are scheduled to occur.

Astronomy at British Universities

IAIN NICOLSON

It is certainly true to say that the major part of astronomical research in the British Isles is carried out at the universities, the only other major contributors in optical astronomy being the Royal Observatories (the Royal Observatory in Edinburgh is, too, linked to the University of Edinburgh) and the Armagh Observatory in Northern Ireland. Outside the universities, radio astronomical research is carried on at the Radio Research Station at Slough, the GPO Research Station, and the Royal Radar Establishment.

A university is a dual-purpose institution, having to combine its rôles of teaching and research without overstressing one at the expense of the other. Because, too, it is an institution where astronomers come into contact not only with scientists working in many and varied fields, but also with the arts and other faculties, the stimulus of academic life would seem to provide a climate of thought more suited to revolutionary work than that in a purely astronomical establishment.

The universities of Oxford, Cambridge, London, Manchester, Edinburgh, Glasgow and St Andrews maintain full astronomical departments, while the physics department of Leeds and Sheffield universities, in particular, carry out research in certain aspects of astronomy. It is also worthy of note that some astronomical work is done by the mathematics and physics departments in universities even if they do not maintain astronomical departments; one does not necessarily have to be a member of the astronomical staff in order to do research in astronomy.

At the undergraduate level it was, until recently, possible to take a first degree in astronomy at only three universities, London,

Glasgow and St Andrews. However, the session 1965–66 sees the commencement of a full course for B.Sc. Honours in Astrophysics at Edinburgh University. It does seem, though, that taking a first degree in astronomy is largely a Scottish custom!

The form of the degree course in those four universities is fairly similar, the major difference being that the degree course is of three years' duration in London, whereas four years is normal at the Scottish universities. In each case, ancillary mathematics and physics is normal in the first two years of the course.

At St Andrews University, of which I can speak from personal experience, the full course for a B.Sc. Honours degree in pure astronomy would normally consist of: First year – astronomy, physics, pure mathematics, and, if possible, applied mathematics in addition. Second year – physics, and either pure or applied mathematics (all three if the student happens to be exceptionally able). This would be followed by a two-year specialist course in astronomy, with additional lectures in aspects of mathematics, applied mathematics, and physics of particular interest to the astronomer. It is also possible to take astronomy as a combined degree with mathematics, applied mathematics, or physics, all of which are useful combinations, and have additional attraction to those who are drawn to astronomy but who feel that a pure astronomy degree is somewhat restricted inasmuch as it does not provide a full qualification for any other branch of science. It is interesting to note, though, that one need not have a degree in astronomy itself in order to pursue research in the subject; physics, mathematics, and applied mathematics are all suitable.

In view of the fact that a fair amount of mathematics and physics is a necessary preliminary to a course in astronomy, the first-year course in astronomy is a very general one, covering a very broad front of astronomical knowledge without going into much detail. Topics include recent developments, the history of astronomy, elementary spherical astronomy, and celestial mechanics. There is also a practical class, one evening a week, at which the use of some basic instruments is demonstrated. The student becomes familiar with the sky, various objects of interest are

studied, and lectures supplemented. This class is taken by many students who do not intend to pursue the subject further; out of a class of perhaps fifty, only a small percentage will take astronomy at a more advanced level.

During the two Honours years, most branches of astronomy are intensively covered, the final degree examination consisting of five papers, each of three hours' duration; an oral examination, and an essay on an approved topic. Students taking combined degrees will sit six or seven papers, roughly half on each subject.

The department at St Andrews is in a state of expansion at the moment, and a separate student observatory is nearing completion (indeed, it ought to be in use before this article appears in print). It will be equipped with a 16-inch reflector, together with a 4-inch refractor and various smaller instruments.

The general pattern of the degree courses in the other universities is similar, though the London (University College) course in pure astronomy is more intensive than in the others. The student body in London is particularly active astronomically, the publication of its astronomical society, *Scope*, having been expanded during the past three years to the *Journal* of the Federation of University Astronomical Societies. The equipment at the University of London Observatory, at Mill Hill, is of course excellent, but it must be admitted that the observing conditions are very poor.

Glasgow University offers astronomy alone, or else combined with physics or mathematics. Here, too, the department is expanding (the first-year class numbers over 100), and a new observatory, with the emphasis on teaching, is under construction; the principal observing instruments are a 10-inch cœlostat for solar work, a 16-inch Newtonian/Cassegrain reflector, a 10-foot parabolic reflector for solar radio work, and a radio interferometer capable of detecting a few of the discrete radio sources.

At Edinburgh there is the unique situation – beneficial to both sides – of the combination of a university astronomical department and a government research establishment (the Royal Observatory). Here, too, the department is expanding, and first

degrees in astrophysics are now being introduced. (The first astrophysics graduates are expected in 1967, i.e. from the first-year students of session 1963–64.) The course is similar to that described for St Andrews, but the Honours years more closely resemble the combined physics and astronomy course at St Andrews.

Although no astronomy degree is offered at Oxford, it is possible to take a degree (generally in physics) with a fair astronomical slant. Three astronomy courses are available. At first-year level: 24 lectures on spherical astronomy, galactic structure and elementary astrophysics. At second-year level: 8 lectures, and at third-year level also 8 lectures, on advanced astrophysics in the Physics Finals course.

For those who do not wish to take a degree in astronomy itself (either singly or combined), it is possible, at London and Cambridge, for mathematics students to take astronomy as part of their course, while at Cambridge, Oxford, Manchester, Edinburgh and Birmingham, physics students may take astronomical subjects during their degree courses.

Purely optical astronomical research in the British Isles is somewhat restricted on account of the unpredictable, and generally poor, observing conditions. There is, too, a distinct lack of large instruments, increasing the tendency for observations to be made abroad and the results brought back to the U.K. for analysis. In radio and theoretical astronomy the present position is very healthy. Research at immediate post-graduate level is generally directed toward producing a thesis for the M.Sc. or Ph.D. degree. At this level, the graduates, usually those with 1st or 2nd Class Honours, normally do one year's research (for the M.Sc.) or three years (for the Ph.D.) in an approved topic, at the same time taking further lectures in the most recent developments. Naturally, the line of research which can be pursued for a higher degree is tied to the type of research which is carried out at the university concerned, and for which the department is equipped.

Cambridge is still something of an astronomical Mecca, and much of the leading research into fields such as radio astronomy, theoretical astrophysics, and cosmology is carried out here. There

are good optical facilities, and excellent observational radio-astronomy equipment (the Mullard Radio Observatory, Cavendish Laboratory). Much of the theoretical work is carried out nominally by the Department of Applied Mathematics and Theoretical Physics. All departments have access to a large electronic computer, without which the reduction of data would be an exceedingly slow and painful business. The computer revolution is spreading through the whole of science, and astronomy in particular is profiting greatly from it. At Cambridge, research is also carried out into dynamical astronomy, photometry, stellar and galactic structure, solar physics and astronomical optics. The university benefits considerably from the exchange of observations with foreign research centres.

London University is well-equipped optically, at Mill Hill, but much of the observing has to be done abroad on account of the poor observing conditions; Mill Hill Park is completely surrounded by built-up areas, and a main road runs about fifty yards from the observatory! London is particularly strong in planetary and space research, solar physics, spectroscopy and stellar structure, while much theoretical work is done, particularly in cosmology.

Manchester University is best known in the field of radio astronomy, with the world's leading equipment installed at Jodrell Bank. Much work is also done in planetary and space research, plus astrophysics, stellar dynamics, and astronomical optics.

Observational research at Oxford is mainly in optical astronomy. The principal programmes are in solar physics, stellar physics, space research, laboratory spectroscopy, studies of interplanetary material, and studies of new techniques in astronomy. As in the other universities, increasing use is being made of foreign observing facilities.

Most of the observational work of Glasgow University is done at large observatories elsewhere, such as at Kitt Peak in the U.S.A., although some direct observing facilities are available at Glasgow itself. Theoretical topics are prominent – in particular, celestial mechanics, stellar dynamics, stellar and solar physics, and the physics of close binary stars.

Edinburgh University has the facilities of the Royal Observatory at its disposal, including a 36-inch reflector and a 24-inch Schmidt. Most of the research work is concentrated on photometry and spectrophotometry, galactic structure, space research (space telescopes, etc.), instrumentation, automation in astronomical techniques (the Observatory is in this respect one of the most advanced in the world), and satellite tracking. Not strictly astronomical, but of considerable allied interest, are the steps being taken to set up an international seismic centre at the Observatory.

The main research instruments at St Andrews are two Schmidt telescopes, one with an 18-inch mirror, and the other of 37 inches, making it the largest instrument in the United Kingdom. Some observational work for St Andrews is done abroad. Photometry of stars and galaxies, galactic structure, stellar physics, and investigations of minor planets are among the principle lines of research, with theoretical work very prominent. The recent installation of a new computer in the Observatory building will assist programmes considerably.

Some radio astronomy is carried out at Sheffield University, while at Leeds University work is done on stellar structure and magnetohydrodynamics. Dynamical astronomy is pursued at Durham University, and some astrophysics at Birmingham University.

The overall state of astronomy in British universities is encouraging, in that many departments are expanding at the present time. Our position in observational radio astronomy is of course outstanding, both with regard to observations, techniques and equipment.

There seems, though, to be a 'wind of change' blowing through our universities, and it may not be altogether a good one. There is a desire, natural enough, to produce as many qualified scientists and technicians as possible to enable Britain to keep pace in technological development, but this seems to be bringing with it a change in the old academic institutions. The attitude of mind of science students and the gearing of the teaching machine seems to indicate that universities are becoming less and less institutions

where knowledge is sought out of interest, and more and more places which may be called 'knowledge factories', where the sole aim of learning is to produce an end-product. While some benefits to society may accrue from this, such a change in the attitude of mind of the university population can have only a harmful effect upon a pure science such as astronomy, and the beneficial effects of academic life on original astronomical research may be lost. However, time will tell.

Recent Activities in Space

H. G. MILES

The launching of a routine satellite no longer creates much interest to those who are not immediately involved in space research. It is, however, these satellites that make possible the more spectacular feats which have taken place recently. In the last few years, the rate of launching satellites has increased considerably. Table 1 shows the number of satellites launched since Sputnik 1 started the space age in 1957.

Year	Number of satellites (including space probes)
1957	2
1958	8
1959	14
1960	21
1961	38
1962	78
1963	72
1964	103
1965 (first 3 months)	34

Table 1

The activities of man in space always reach the newspaper headlines. Recently we have seen the close of the age when single astronauts circled the Earth, the Mercury capsules being replaced by the two man Gemini vehicles and the Vostoks by the multi-seater Voskhod series. After Gagarin's journey in Vostok 1, possibly the most dramatic experiment has been Leonov's venture

into space connected to Voskhod 2 only by a nylon rope. Sensational as these feats appear now, they will without doubt fade into oblivion as the 'Man on the Moon' projects progress.

Before man can go to the Moon, many questions about the lunar surface must be solved. The first stage of this long and difficult project has, nevertheless, just been successfully concluded. Despite many teething problems in the early stages, the Ranger programme finished in a blaze of glory, the last three (Rangers 7, 8 and 9) sending back a total of 17,259 first-quality photographs of the lunar surface, many of them showing detail impossible to be obtained using Earth based cameras.

Each probe carried six television cameras mounted in the truncated cone above the hexagonal base. All the cameras had a five-element fixed focus lens capable of handling distances from infinity down to a few thousand feet. The focal plane shutter was not cocked as in conventional cameras but moved from one side to the other each time an exposure was made. Two of the cameras were designated F (for full scan) and four P (for partial scan). The F1 camera contained a 25 mm. F/1 lens giving a field of view of 25 degrees and the F2 camera, a 75 mm. F/2 lens with a 8·4 degree-field. The image in each case was projected on to the face of a videcon tube, 1 inch in diameter, the actual image being 0·44 inches square. The picture was scanned using 1,152 lines by an electron beam and the signal subsequently transmitted back to Earth. They were received via the two 85-feet parabolic aerials at Goldstone and recorded on 35 mm. film and also on magnetic tape. The camera sequencer on board the probe sent instructions alternately to each camera at 2·56 second intervals. When one camera was taking a picture and transmitting it back to Earth, the other was clearing the videcon tube.

To speed up the process of sending back pictures (2·56 seconds was far too great a time interval, especially as the probe drew close to the Moon), the four P-cameras, similar optically to the F-cameras, gave a much reduced field of view. The image size was reduced to 0·11 inches square and was scanned using 300 lines. By this means it was possible to transmit a picture every 0·2 second.

The main power supply of about 200 watts came from 10,000 solar cells contained in the two panels extending on either side of the main body. At times when the probe was not sun-orientated (as in the launch phase and during the mid-course manœuvre) power was supplied by two silver zinc batteries. Separate batteries were provided for the TV system.

To send a spacecraft to the Moon requires in the first instance the sending of the vehicle through a 10 mile diameter target 120 miles above the Earth's surface at a speed within 16 miles per hour of 24,470 miles per hour. If this accuracy is achieved on launch, the mid-course manœuvre can be carried out to enable the probe to be put on the Moon in the desired area. In each case, the required accuracy was achieved and the three Rangers were able to land very close to the predicted points. With Ranger 9, the error was only 2·6 miles. The mid-course motors were capable of making very small corrections. They could be fired for as short a period as 50 milliseconds and were capable of altering the velocity of the probe by increments of 1·2 inches per second up to 190 feet per second.

When calculating the trajectory for the journey, due allowance had to be made for the gravitational pull of the Earth, Moon, Sun, Venus, Mars and Jupiter! Consideration had to be paid to the mechanical limitations of the spacecraft, a moving launching site and restrictions imposed by the location of the tracking stations. For example, when the probe approached the Moon, it was necessary for the latter to be above the horizon at the tracking station. Launch limitations were also imposed by photographic considerations. At new moon, most of the surface facing the Earth would be in darkness and consequently useless from a photographic point of view. During the period of full moon, attitude control requirements could not have been attained. In addition, near vertical lighting would have reduced the quality of the pictures. In the first quarter, the sunlit side is the following half and technical limitations make it quite difficult to carry out the experiment. Consequently all the Rangers were sent close to the last quarter of the lunar cycle.

Ranger 6, launched on 1964 January 30, landed on the Moon within 17 miles of the predicted target in the Mare Tranquillitatis, the Sea of Tranquillity, but unfortunately the camera system did not work. Much research went into investigating the reason for the failure and it is now believed that the television systems were accidentally switched into the warm-up mode during launch and that arcing took place whilst the rocket passed through the critical low pressure region between 140,000 and 250,000 feet, the arcing damaging the transmitter and possibly the camera systems. Subsequent Rangers were modified to prevent premature activation of the camera systems. Ranger 7 landed on the Moon on 1964 July 31 in the region of Mare Nubium, the Sea of Clouds. On this occasion everything worked according to plan and 4,316 high resolution photographs were successfully received at Goldstone. The resolution obtained was 2,000 times better than any photograph taken by Earth based instruments. The impact area has since been named the Mare Cognitum, the 'Sea that has become known'. This region is streaked with rays from the crater Tycho and it appears that these rays consist of thousands of small craters. From the information gained, it was decided to send the next probe to an area which was free of rays. Accordingly, Ranger 8 was programmed to photograph the region of the Mare Tranquillitatis. It hit the Moon on 1965 February 20 in the required area, quite near to the well-known craters Sabine and Ritter, but before it did so, it successfully transmitted 7,137 pictures, showing craters and general surface features similar to those obtained by Ranger 7.

To obtain information on the surface conditions in the region where there are many large craters, the target for Ranger 9 was the famous crater Alphonsus, in which the Soviet astronomer Kozirev reported volcanic activity in 1959. The actual target was chosen to be very near to the terminator so as to give better detail and more contrast. Accordingly, to cope satisfactorily with the light values near the terminator, the sensitivities of the F/2 lens cameras were increased, the F/1 cameras remaining the same as for the previous flights. Ranger 9 landed near the central peak of Alphonsus on

1965 March 24 after sending back 5,814 top grade pictures, the first from a height of 1,405 miles and the last 2,000 feet above the lunar surface.

It is too early to give an accurate assessment of the findings from the photographs. It does seem, however, that although a tremendous amount of new data has become available, the arguments between the exponents of the meteoritic and volcanic theories will carry on until possibly a soft landing is made on the Moon and the rocks analysed. One famous American astronomer said recently that on looking at the photographs, each investigator sees overwhelming evidence to support his own particular theory!

The information obtained from these probes has not been limited to a study of the surface features. From impact times of Rangers 6 and 7, a new value for the lunar radius has been obtained, 1,735 kilometres – 3 kilometres less than the previously accepted figure. More accurate values for the masses of the Earth and Moon have been obtained, the accuracy of the latter being improved by a factor of 30.

Soon after the end of the Ranger programme, the Russians fired a lunar probe, Lunik 5, with the object of attempting a soft landing on the Moon's surface. The retro-rockets, however, did not fire at the correct time and the probe crash-landed on the Moon. The satellite tracking station at Rodewisch, in East Germany, reported observing dust clouds caused by the braking rockets in an area around the Mare Nubium. The dust clouds were recorded photographically and at maximum visibility the cloud covered an area measuring 140 miles by 50 miles. The cloud subsided rapidly and was hardly visible 6 minutes later.

From the point of view of the layman, the most striking advances have been made in the field of communications. The positioning of Syncom 3 in stationary orbit 22,300 miles above the Pacific Ocean enabled the Tokyo Olympic Games to be seen by viewers in the Western hemisphere. From the British point of view, the launching of the world's first commercial satellite, Early Bird 1, into a stationary orbit over the Atlantic Ocean has enabled continuous contact between Europe and America via satellites

to be achieved. This is the first stage of a global system of communications via satellites. The Communications Satellite Corporation formally came into existence in 1964 August, when eleven countries, including Britain, agreed to the establishment of a global commercial communications satellite system. From the experience gained by Early Bird, the choice of system or systems to be used in future projects will be agreed late in 1965.

The power system of Early Bird consists of solar cells supplying 45 watts whilst the satellite is in sunlight. During eclipse periods, which will occur principally near the vernal and autumnal equinoxes, it is possible that the satellite will be in the Earth's shadow for up to 70 minutes and for these periods power will be provided by nickel cadmium batteries. In size and appearance Early Bird is similar to Syncom. It is capable of transmitting 240 two-way voice channels for telephone use, high speed data or television.

Although the effect of long range TV may affect the lives of many millions of people on both sides of the Atlantic Ocean, it is the inhabitants of the Eastern regions of the United States who are most thankful for the progress of space research. The Tiros weather satellites have, since 1960, tracked and reported most of the tropical storms and hurricanes which have approached the United States. From about half a million pictures, the U.S. Weather Bureau have issued over 1,000 storm bulletins. The launching of Tiros 9 in 1965 January opened the second chapter in reporting global weather. This satellite is the trial run for the fully operational system to commence at the end of this year. Unlike the earlier Tiros satellites, which were space orientated, permitting photographs to be taken only once during each revolution round the Earth, Tiros 9 rotates roughly ten times per minute about an axis perpendicular to the plane of its orbit round the Earth. The two cameras on board the satellite are situated on the rim and hence each camera can take a photograph every 6 seconds. Although the orbit actually achieved was not exactly the planned one, photographs have been obtained of most of the Earth's surface, and for the first time global pictures of the Earth's cloud cover

have been obtained. Unfortunately, one of the cameras failed after the satellite had been in orbit for a few weeks but the other is still sending back 250 cloud pictures daily.

Although one can consider satellites designed to study the Sun, the upper atmosphere and interplanetary space as part of the 'Man in the Moon' project, they are of course of great importance in their own right. From an astronomical point of view possibly the most important launching occurred on 1965 February 3 when the second orbiting solar observatory – OSO 2 – was successfully put into orbit. The previous one, OSO 1, launched in 1962 March, investigated solar emission in the ultra-violet and X-ray regions.

OSO 2 has two main sections, the spinning base and the top section called the sail which points continuously towards the Sun when it is visible. A scanning mechanism enables the whole solar disc to be monitored in ultra-violet and X-radiation. Two out of the five Geiger counters scan the solar disc in greater detail, taking 4 minutes to cover the whole disc. One of the counters looks for prominences round the edge of the disc. In the corona experiment, the Sun is artificially eclipsed and the corona is mapped in white light and in the light of three wavebands in the UV region. Another experiment concentrates on the high and low energy gamma radiation.

In the testing of the Saturn rocket, the opportunity has been taken to launch a satellite to measure the concentration and distribution of micrometeorites. The satellite, Pegasus 1, was launched on 1965 February 16. When in its operating mode, Pegasus measures 96 feet by 14 feet, giving more than 2,300 square feet of detecting surface. The centre section houses the electronics systems, the solar panels and the deployment mechanism for the winged structure. Each wing consists of seven hinged panels, the hinges being spring loaded so that the wings would open in an accordion fashion.

Each panel consists of a thin aluminium sheet of varying thickness up to 0·016 inch. Beneath the aluminium sheet is a layer of mylar plastic and then a layer of thin copper. This sand-

wich is mounted on a soft foam and this in turn is mounted to a rigid foam central core. The copper and the aluminium form a condenser and a potential of 40 volts is placed across the plates. When the panel is penetrated by a meteoroid, the metal removed by the impact is vaporized forming a conducting gas which discharges the condenser. The gas dissipates almost immediately and the condenser is recharged in 0·03 seconds.

When a hit is registered, the actual panel punctured is recorded together with the time and the direction of the Sun. The actual number of hits being registered is comparable with the estimated density of these particles. Two more similar satellites are scheduled to be launched during this year.

One of the most ambitious projects so far attempted is the sending of probes to the planet Mars. The Russians have sent two but unfortunately both have suffered a similar fate. The second probe, Zond 2, failed to be contacted at the end of April this year. It was reported soon after launch that the probe was transmitting on only half power so it appears that the trouble lies in the telemetry system.

The American Mariner 4, on the other hand, seems to be working quite well. It is transmitting information on conditions in the region lying between the orbit of the Earth and Mars. The camera systems for taking photographs of the Martian surface have been activated successfully ready for its encounter with Mars in the middle of July. The latest information (May 6) gave the distance of the probe from the Earth as 72 million miles, it having travelled 243 million miles along its trajectory towards the planet.

Recent Advances in Astronomy

PATRICK MOORE

There was a time, not so very many decades ago, when astronomy could be said to have been in a more or less static condition. A book published at any particular time could well be reprinted ten to twenty years later without any really major modifications, and spectacular advances were rare indeed. This is certainly not true today, when progress is so rapid that a luckless writer may well be out of date before his work appears in print. Neither is it possible to produce a book within a few weeks, and it must be made clear that the present article is being written in June 1965; by the time that this *Yearbook* is published, in the late autumn, much more may well have happened.

In space research, developments have been particularly quick. We have come a long way since 1957 October 4, when the Russians opened the Space Age by their dramatic and (in the West) totally unexpected launching of the first artificial satellite, Sputnik I. And it is less than six years ago that Yuri Gagarin became the first true astronaut in human history; by now, a new manned orbital venture scarcely reaches the headlines of the daily newspapers – except when something really new is achieved, as with Colonel Leonov's 'walk in space', subsequently accomplished also by the American astronaut Major White.

Probably the most significant point about these exploits is that neither astronaut appears to have been affected by radiation, and the prospects for lengthy journeys in space seem brighter than was the case a year ago. In view of the success of the unmanned Ranger lunar probes, the Americans are confident that they will be able to place a man on the Moon within the next few years, and it is not likely that the Russians, despite their recent setbacks, will be far behind.

The Ranger results have been described by Howard Miles in his article, and there seems no need to dwell upon them here, except to repeat that the photographs – magnificent though they are – have not cleared up the vexed question of the lunar surface structure. At an international congress held in London in the summer of 1965, it was clear that the differences of opinion were as wide as ever, with the supporters of the dust-drift picture still unshaken in their views, while others were equally confident that the Moon's crustal layer is quite firm enough to support the weight of a space-craft. Neither can we be sure, as yet, whether the lunar craters are due to volcanic action or to plunging meteorites. It is difficult to be unprejudiced, and I see no reason to alter my contention that vulcanism has been the most important process in crater production, but positive proof one way or the other must await the first successful 'soft landings', in which a vehicle is brought down gently enough to avoid damage to its equipment. The Russians, having failed in May 1965 with Lunik V, were again unlucky in the following month, with Lunik VI. Launched on June 8, the probe was evidently designed for a soft landing, but during a correction manœuvre, on June 9, an engine which had been switched on by remote control obstinately refused to allow itself to be switched off again. The result was that the whole orbit was changed, and Lunik VI missed the Moon by as much as 100,000 miles, subsequently entering an orbit round the Sun and becoming yet another tiny artificial planet.

It is rather surprising to remember that the Russians have not sent up successful lunar probe since October 1959, when Lunik III went right round the Moon and sent back the famous photographs of the averted hemisphere. Clearly they are having serious trouble with their instrumentation, and it is a sad reflection upon human intelligence that political considerations prevent American instrumentation being combined with Soviet launchers, since it seems definite that so far as propellants are concerned the Russians are still well in the lead.

The same troubles beset the Russian probe to Mars, Zond II, which was lost when still well short of its target; contact with it

will never be regained, so that its final fate will remain unknown. However, the U.S. vehicle Mariner IV showed signs of being much more successful, and was expected to pass reasonably close to Mars in mid-July, sending back pictures of the dark area known as the Mars Sirenum. At the time of writing, Mariner IV is still on course, and still transmitting strongly.

Much remains to be learned about Mars, and recent doubts have been expressed about the chances of life there. For some years, the idea that the dark areas are due to organic matter has been almost universally accepted, and spectrographic work by W. Sinton in America was regarded as practically conclusive. It now seems, however, that there may have been errors in interpretation, and it is too early to say definitely that Mars is a planet upon which low-type vegetation flourishes.

From time to time, experiments have been made with the object of studying the behaviour of organic matter under simulated Martian conditions. Work has been carried out in America, and research was also undertaken in Britain by F. L. Jackson, who built 'Martian containers' with the correct atmospheric pressure and composition and the correct range of temperature between day and night; it was found that certain terrestrial life-forms of the microscopic variety could definitely survive, though a single Martian night was fatal to larger forms. Some new experiments have now been made in Russia by A. Zhukova and I. Kondratyev, who followed the same procedure, but also introduced radiation similar to that received by Mars from the Sun. The atmospheric composition was taken as 95·5 per cent nitrogen, a small quantity of carbon dioxide, and only one part in 200 of oxygen. This may or may not be correct, but at least it agrees with the best available determinations.

Zhukova and Kondratyev confirmed that microscopic life-forms can survive under Martian conditions, but this need not necessarily mean that life there really exists, and such experiments, significant though they may be, are not conclusive.

Mercury, the innermost planet to the Sun, has also been very much in the news, though so far there has been no serious talk of

sending a probe to it. Because Mercury, with its diameter of 2,900 miles (rather less than the older value of 3,100 miles) is not a great deal larger than the Moon, never comes much within fifty million miles of us, and is not easy to study because it remains close to the Sun in the sky, our knowledge of its surface is very limited, and there has been no improvement upon the chart drawn up more than thirty years ago by the Greek astronomer E. M. Antoniadi. Yet it has been accepted that the rotation period is the same as the period of revolution round the Sun (88 Earth-days), in which case Mercury would keep the same face turned permanently sunward. Part of the planet would have perpetual daylight, while another part would be plunged into never-ending night, and between the two extremes there would be a 'twilight zone' over which the Sun would pass above and below the horizon. The atmosphere is extremely tenuous, and life of any kind appears to be out of the question.

In the spring of 1965, some unexpected results were announced by research workers at Cornell University's Arecibo Ionospheric Observatory in Puerto Rico, where an immense paraboloid has been built in the ground; the paraboloid is not steerable, and so cannot be compared with the 250-foot dish at Jodrell Bank, but it is much larger. So far as Mercury was concerned, however, the discoveries were made not by true radio astronomy, but by radar. Pulses reflected from the far-away, elusive planet indicated that the rotation was not in fact a captured one. According to Drs R. B. Dyce and G. H. Pettengill, as reported in Washington to a meeting of the International Scientific Radio Union, there are two possibilities:

1. Mercury rotates in the same sense as the Earth (i.e. west to east) in a period of 59 days.
2. Mercury rotates in a sense opposite to that of the Earth (i.e. east to west) in a period of 46 days.

In either case, there is an uncertainty of five days either way. If the results are confirmed, then all our ideas about the physical situation on Mercury will have to be drastically revised. There

will be no day-zone, no region of eternal night, and no twilight land between the two, so that every part of the planet will be in sunlight at some period during the 88-day 'year'.

It would be idle to pretend that all astronomers are satisfied about this, and observers are uncomfortably aware that a rotation period of less than 88 days would render all published maps of the surface completely obsolete. There is certainly an urgent need to re-examine the planet, but this means the use of very large telescopes, which are already fully committed to work which is regarded (justifiably) as more important. However, one may hope that a certain amount of time will be spent on the problem, preferably with a giant refractor. Antoniadi used the 33-inch instrument at Meudon Observatory, but since then nobody has studied Mercury intensively with a comparable aperture. Of course, only the broader details could be recorded; if Mercury has lunar-type mountains and craters, which appears to be quite likely, there would be little hope of detecting them.

Venus was also studied from Arecibo, and it was found that the rotation period was 247 days, again with an uncertainty of 5 days either way. This agrees well with earlier determinations, and with the results from the famous 1962 Venus probe Mariner II, but here too not every authority is entirely satisfied; it is a strange situation to find a planet in which the rotation is slower than the revolution period – and Venus takes only 224·7 days to complete one journey round the Sun. It may be added that the radar work also indicates that Venus has a surface at least as rough as that of the Moon.

Far beyond the inner planets lies Jupiter, the giant of the Solar System, and a favourite object for the amateur astronomer who is anxious to carry out some useful work. The belts crossing the planet are always spectacular, and are always changing; during recent years they have been exceptionally active, and the enigmatical Great Red Spot has been much in evidence. We cannot claim to know the origin of the belts, but a new idea has been put forward by the Kiev astronomer S. K. Vsekhsviatsky, who supposes that they are 'regions of saturation of ash particles ejected during intense volcanic cataclysms'. This is an interesting theory,

but it is quite unproved, and we are still very much in the dark as to the internal constitution of Jupiter and the other giant planets. There may or may not be a true solid surface.

One of the most fascinating features of Jupiter is its activity in the radio range. Radio waves from Jupiter, first detected in 1955 by Burke and Franklin, have provided astronomers with plenty of problems, and the situation has been further confused by the fact that the frequency of emissions seems to be linked with the position in orbit of Jupiter's innermost large satellite, Io. Developments here are described by F. W. Hyde in his article, but I may perhaps be allowed to add that my own observations of the surface features, compared with the radio results, indicate that there is no connection between visible markings and Jovian radio sources.

A sad event in 1965 was the sudden and unexpected death of B. M. Peek, the British amateur astronomer who had achieved an international reputation as an observer of Jupiter, and whose book on the subject is accepted as the standard work. Peek died during a visit to Australia, and is badly missed by his many friends and colleagues all over the world.

On the boundary of the planetary system, remote Pluto moves in its vast orbit, taking 248½ years to complete one circuit, and appearing as little more than a speck of light even in the world's largest telescopes. It was discovered in 1930, by Clyde Tombaugh at the Flagstaff Observatory, as a result of calculations made years earlier by Percival Lowell – and it has been a puzzle ever since. It has an orbit which is most unusual for a true planet, since the eccentricity is relatively high, and at perihelion it approaches the Sun well within the distance of Neptune. The next perihelion passage will take place in 1989, so that Pluto is already appreciably brighter than at the time of its original discovery, and a moderate instrument will now show it.

Lowell tracked Pluto down by the perturbations which it exerts on the major planets Uranus and Neptune. Yet when the diameter of the new body was measured, it was found to be only about 3,600 miles, less even than that of Mars. Unless the density were improbably high, this would mean that Pluto could not

perturb either Uranus or Neptune to any measurable extent, and it was suggested that Lowell's accurate prediction had been due to sheer luck.

Much later, variations in the light of Pluto allowed the rotation period to be fixed at 6 days 9 hours. Studies of the light-curve have now indicated that the planet is distinctly larger than was previously thought; the diameter may in fact be at least as great as that of the Earth, and the surface is not uniformly reflective. The conclusions are tentative as yet, but it is quite on the cards that Pluto's mass, too, is greater than has been thought, in which case Lowell's accuracy is fully vindicated.

Two eclipses of recent months deserve to be mentioned in any survey of Solar System studies. On 1964 May 30 there was a total eclipse of the Sun, but, with typical perversity, the track crossed only the Pacific area. This was inconvenient, but astronomers were not daunted; they were particularly anxious to observe the eclipse, since the Sun was at its minimum activity, which affects the corona and other eclipse phenomena. Various expeditions were dispatched, mainly to Manuae in the Cook Islands, where totality lasted for over 5 minutes.

One might expect good weather in the Cook Islands, but on this occasion luck was against the astronomers, and during totality the Sun was hidden by cloud. Some results were obtained from aircraft, but generally speaking the programme was unsuccessful. It can only be hoped that better fortune will attend the two total solar eclipses of 1966, one (May 20) in the Greece and Turkey area and the other (November 12) in the North Pacific and parts of South America. For the May eclipse, totality will be extremely short.

A partial lunar eclipse on 1965 June 14 was fairly well observed in Europe; despite the Moon's low altitude, many reports came in from England. Unfortunately only 20 per cent of the disk was covered by shadow. It seems that the eclipse was lighter than the two total lunar eclipses of 1964, which had been unusually dark because of dust and ashes sent into the upper atmosphere of the Earth by an earlier volcanic outbreak in the East Indies. By mid-1965 much of this material had apparently settled.

It is tempting to dwell upon our own Solar System, because we live inside it, and to us it is of vital importance. Yet it should always be remembered that in the universe as a whole, the Solar System is entirely insignificant; even the Sun is only one of some 100,000 million stars in the Galaxy, and is certainly not above the average in size or luminosity. Officially, it is ranked as a Yellow Dwarf of spectral type G, which is an unflattering but perfectly accurate description of it. Since it has a family of planets, there is no reason to doubt that other similar stars have planetary systems of the same kind, and it is only one step more to suppose than many of these 'other planets' may be populated by intelligent beings far in advance of ourselves both technologically and morally. Most astronomers now consider that life is widespread in the universe, both in our Galaxy and in other galaxies.

Contacting other beings is, of course, an extremely difficult matter. The distances involved are so vast that anything in the nature of a rocket probe is out of the question, and in all probability will remain so even in the remote future. The one hope is to use radio, and some years ago a definite programme was carried out by F. Drake and his colleagues at the Green Bank Radio Astronomy Observatory in the United States, who concentrated upon a wavelength of 21 centimetres. This particular wavelength was selected because it is that of the radio emission sent out by the clouds of cold hydrogen in the Galaxy, and any advanced beings on another world, wherever they might be, would be certain to pay attention to it.

The experiment was a very long shot indeed; nobody seriously expected it to yield tangible results, and it was soon discontinued, but the whole question of extra-terrestrial life has remained in the fore, and in April 1965 a remarkable statement from the U.S.S.R. caused intense interest all over the world. It was said that N. Kardashev and G. Sholomitsky had been studying a distant radio source, CTA-102, and had found it to be varying in a strangely regular manner. The two Russians claimed that the signals must be artificial, and that a super-civilization had been discovered at last.

This was, to put it mildly, a bad case of jumping to conclusions

without adequate supporting evidence, and the rest of the world was frankly sceptical. Before long the claim of a super-civilization was quietly dropped, to be replaced by a more sober and scientific approach to the whole matter.

CTA-102 is an object of the kind known as a quasi-stellar object, a quasar, or (for short) a QSO. It looks very much like a star, but in fact it is quite different; it is shining 100 times more brilliantly than an ordinary galaxy, and since it is relatively small it must be drawing upon some energy-source quite unknown to us. It is not unique. Other QSOs are known, some of them thousands of millions of light-years away. They are believed to be the brightest objects in the entire universe, and they are certainly the most mysterious. The most remote of them is said to be receding from us at two-thirds of the velocity of light.

In June 1965 yet another discovery was made, this time by the American astronomer A. Sandage. Previously, the QSOs had been identified with strong radio sources; indeed, it was by their radio emission that they had been tracked down, since previously they had been taken for normal stars. Sandage then announced that in addition to the radio QSOs, there were a great many objects which could be termed 'quiet QSOs' – that is to say they were equally luminous and equally distant, but were not strong radio sources. They had been taken for young, bluish stars in the halo surrounding our own Galaxy, but their spectra showed otherwise.

The identification of QSOs, both radio and quiet, is certainly the most important astronomical event of recent years, and it may well lead on to a solution of the vexed question of the past history of the universe; at present there is continuous argument between the supporters of the steady-state theory, according to which the universe had no beginning and will have no end, and those who believe that the universe came into existence at one set moment, so that it is steadily evolving and will not last for ever. It is too early to speculate as to what new discoveries will be made during the next year or two, but it may not be out of place to introduce a note of caution.

It is generally said that the universe is in a state of expansion, so that all the groups of galaxies are receding from all the other groups; the farther away a galaxy lies, the faster it is moving away. This depends upon what is known as the spectral red shift. Broadly speaking, an object which is receding will look somewhat redder than it would do were it at a constant distance; the actual colour-change is undetectable, but the effects show up in the spectrum, which is shifted bodily over toward the red or long-wave end. This is an example of the Doppler effect, familiar to anyone who has more than a passing interest in science.

The QSOs show very large red shifts, which is why they are held to be so remote and to be receding so quickly. But suppose that the red shifts are not due to the Doppler effect at all? In this case, not only the QSOs, but also the outer galaxies might be much closer than has been thought, and the idea of an expanding universe might have to be given up.

Perhaps this is not very likely, but it is at least a possibility, and the last word has by no means been said. More research is needed, and will certainly be carried out. Astronomers will be most reluctant to abandon the idea of universal expansion, because it would mean that virtually all the cosmological theories of the past forty years would have to be abandoned too, but it would be foolish to be over-confident. There is a chance, slight but not negligible, that the identification of the QSOs will lead us on to some drastic re-thinking.

New Horizons[1]

FRANK W. HYDE

Perhaps the most exciting thing about scientific research is the fact that there are always new horizons, there is always something new to come in the future; sometimes this occurs in fields which have been well explored, sometimes it comes in fields which are entirely new. Sometimes, indeed, it occurs when someone unconnected with the line of research suddenly offers a new point of view. One instance of this concerns the radiations from the planet Jupiter.

For ten years various investigators have studied the particular radiations of Jupiter which occur in the decametre range, i.e. tens of metres in the length of the wave. Many different approaches have been made, and a great deal has been published on the subject. The initial discovery was revealed by Burke and Franklin of America and since then much has been learned about these radiations, but nothing at all of their origin. Many theories have been put forward but none of them has found universal acceptance. One cannot predict when the emissions will appear, but all workers are reasonably satisfied that the Sun has something to do with it, although precisely how this works nobody can tell.

Statistics showed that there were three areas which appeared to give rise to these radiations; these were recorded in different ways in different parts of the world. The most extensive chain of stations is that set up by Florida State University which extends from Norway through England, Spain, Africa, Tallahassee (Florida) and Jamaica. Each year of observations reveals some new facet of this interesting problem.

However, it remained for someone entirely unconnected with

[1] For an alternative view of some of the material in this article see Patrick Moore, *Recent Advances in Astronomy*, p. 135

the work to suggest a new point of view of somewhat startling character. A meteorologist, K. Bigg, from Australia, was visiting the observatory of J. W. Warwick in America where he was given access to four years of data. These data are probably the most extensive collected in the Jupiter field, for the system adopted by Warwick monitors frequencies over a very wide band continuously. Bigg examined the data and produced a result which suggested that one of Jupiter's satellites, Io, was in fact very largely concerned with this radiation. Naturally in the past the possible effects of satellites had been considered but no one had actually made any comparisons between the revolution of the satellite Io round Jupiter and the radiations from Jupiter. A new point of view such as this met with a certain amount of scepticism, but it rapidly become apparent that there was something very significant here. Now this hypothesis has to be explored and experiments set up to check just how much effect Io has. It has also brought another satellite of Jupiter into prominence, the innermost large satellite, which has an orbital period very little more than Jupiter's own speed of rotation. One of the reasons that led Bigg to attempt this analysis was the fact that Io is somewhat similar to the Moon in respect to its parent planet Jupiter, in size and mass and distance from the parent planet. It is sufficiently small and distant to exert some effect on the magnetosphere of Jupiter itself.

Warwick and Dulk have naturally re-examined their own data, and it would now appear that there are consistently bursts of emission which occur predominantly when Io is in one of two positions. If we measure anticlockwise round the satellite's orbit, these positions are at 90 degrees and 240 degrees from superior conjunction, that is to say when the satellite is behind Jupiter. Here another important point has to be considered and that is the high speed of Jupiter's rotation. The average rotation of Jupiter on its axis is a little short of ten hours; the ratio of the rotational period of the planet and the orbital period of the satellite must therefore be considered. Warwick has believed for some time that Jupiter's magnetic axis is very much inclined to its rotation axis, unlike the Earth where it is only a few degrees from the geo-

graphical rotational axis. If this magnetic axis is inclined to a considerable degree it will be appreciated that it will rotate in a kind of 'wobble' in relation to the planet's axis and therefore, of course, in relation to the satellite. The result of this is that as the planet rotates, the tilt of this magnetic axis is in the direction of the satellite once every thirteen hours. It would appear from the observations that when Jupiter begins to emit radiation in a direction 90 degrees beyond the satellite, the axis is about 60 degrees short of actually catching up with Io. The emission is fixed in its direction with respect to the satellite, and just before the plane of the axis reaches the satellite a second emission begins, and this is roughly in the direction in which the axis appears to be pointing at the start of the sequence. If it is assumed that these radiations are continuous then the effect of Io and the direction of the magnetic axis can explain why it is that the radiations received on Earth are spasmodic, because only if the Earth happens to be in the line of one or other of these beams, as it were, would radiation be received. It may be that Io has a magnetic field of its own and therefore, is able to distort very considerably the magnetic field of Jupiter, or it may simply be that the effect of the satellite in the field of the planet is sufficient to cause the necessary distortion. Perhaps these new discoveries will help to solve some of the problems of the origin of the radiations.

Another peculiarity that has been discovered is that the rotational period of Jupiter from the radio astronomer's point of view, derived from the observation of the various events of radiation, remained constant up to 1960 but lengthened by one second during the years 1960 to 1964. It must be said also that there are problems in other parts of the radio frequency spectrum and other aspects of Jupiter which are being urgently studied and some of this is directed towards the construction of a more accurate model of the structure of the planet, about which we know little or nothing.

Let us move nearer home to our own satellite the Moon. Much has been done in the past year to increase our knowledge of the structure of the surface of the Moon; we have had the Ranger

photographs, some of them so finely detailed that it will be some time before conclusions can be finally drawn. There have been evidences of change of colour and even the possibility in some of the photographs of clouds of dust thrown up by the impact of the probe which took the pictures.

These pictures though extremely good are still, of course, black and white. There are other methods of detection and photography which give some extremely interesting results; the workers at the University of Arizona under G. P. Kuiper and the Observatory at Meudon, under Dr Dollfus, have indicated that the light is more strongly polarized from some regions than from others; the greatest polarization appears to be from the darker areas of the Moon. It is possible with the naked eye to observe that areas are of different luminosity and when observed through filters, areas can be seen where there are predominant colours. It would now appear that this colour is due to the bombardment by the protons of the solar wind. The Moon, unlike the Earth, has no magnetic field to repel these particles which emanate from the Sun; it is possible that the solar wind produces a small magnetic field owing to the fact that the Moon is a poor electrical conductor. There are various opinions about the colours of these patches on the Moon's surface; compared with terrestrial rocks they are a somewhat darker and more distinct group. Professor Gold suggests that this darker hue may be the result of prolonged proton bombardment, and at Cornell University experiments have been conducted on various rocks to see whether a similar discoloration can be produced in the laboratory by proton bombardment. It is found that this can indeed be done.

Perhaps a point of great interest here is that it was found that this could be more easily done with finely divided rocks than with solid rocks. This discoloration may be due to chemical effects; it could also be due to a form of sputtering of the material dislodged by the impact of the protons. All this would seem to support the theory that the top surface of the Moon, at least, whatever thickness it may be, is made of friable rock or may be even a sandy-like consistency.

Another discovery that was made is that the Moon is luminescent of itself, that is that it has a glow of its own quite apart from reflected sunlight. Photo-electric studies have been made of different areas of the Moon by Ring and Granger using a 50-inch telescope at Asiago. They compared the lines in the spectrum of moonlight with the same lines in sunlight and found that there was reason to suppose that luminescent light originated on the Moon, produced by the conversion of some other type of radiation. This luminescent light appeared to vary from 2 to 10 per cent of the brightness of the ordinary light scattered from the Moon. A great deal of energy is required to excite this kind of luminescence. Although there is a continuous bombardment of solar protons they would be many times too weak to provide the stimulus required. However, the ultra-violet of sunlight could account for the effect. Geake and his colleagues at Manchester College of Science and Technology have worked on a hypothesis that the luminescence might be due to the débris of meteorites; they therefore tried irradiating powdered meteorites in the laboratory with both protons and ultra-violet light. Certain types of meteorites were found to fluoresce with protons, but such meteorites are comparatively rare, and the more common ones are much lower in efficiency in this respect. Geake however thinks that long period proton bombardment may well offer a solution. During the 1960 lunar eclipse it was found that when the sunlight was shut off the surface of the Moon cooled unexpectedly quickly, but there were regions, for example, the crater Tycho, which continued to radiate heat at a much higher rate than their immediate surroundings. In December 1964 workers at the Boeing Scientific Research Laboratory scanned the Moon's disk with high resolution infra-red equipment. They discovered that the Moon is speckled all over with a large number of hot spots. This has been substantiated by Murray of the California Institute of Technology. Some three hundred of these hot spots have been recognized, and they present a number of problems. They must indicate at least different kinds of surface conditions, they are not confined to the large craters and many occur in the maria, although night-time measurements

indicate that there are quite characteristic differences between the hot spots in the lunar uplands and the maria and there is no simple relationship in the distribution. It could be that gas, either hot or cold, is being exuded from the Moon and there have of course, been reports that certain craters have in fact given off some kind of vapour.

It would not be right to leave this subject without mentioning Kopal and Rackham, who have made an extensive study of this subject using the Pic du Midi telescope. They have investigated in great detail the craters Kepler and Copernicus. They suggest that some of this phenomenon is due to the effect of solar flares, since they have observed that the residual brightness increases with the increase of the sunspot cycle, and at the time of minimum solar activity drops rather abruptly. It is clear that the Moon, which became relegated to the casual observer, has once again captured the imagination of many schools of thought and no doubt at the next I.A.U. Convention in 1967 there will be many papers on it presented to the members.

In the solar system the nearest planet Mercury and the farthest planet, Pluto, have both come in for considerable attention. In the case of Pluto, astronomers have always regarded it as somewhat of a puzzle. It appears to be somewhat smaller than the Earth and even probably smaller than Mars. It was initially tracked down and its position identified as a result of calculations by Lowell. These calculations were based on the perturbations of Uranus and Neptune.

This in itself raises certain problems, for if Pluto is in fact a small body, it would be unable to produce detectable perturbations on large planets like Uranus and Neptune without having a very considerable density. At the Lowell Observatory in Arizona, Walker and Hardie measured the brightness of Pluto and found that its magnitude varies quite regularly over a period of a few days. They derived from these changes a rotation period of six days and nine hours. Further observations using the Californian reflectors, both the 100-inch and the 200-inch, gave the value of its diameter as 3,700 miles. Later in 1964 Hardie made a new series

of measurements using a 24-inch telescope. Although there were difficulties in the observations the results that have been obtained can be considered reliable.

The rotation period is now thought to be 6 days, 9 hours 16 mins 54 secs with a possible error of less than one minute.

The light curve shows that Pluto brightens over an irregular cycle; for about four days it brightens, then drops to a minimum in two days. Unless we assume a peculiar surface pattern this would mean that the disk is brightest at the centre and darkens towards the limb. Many years ago Crommelin suggested that the apparently small size of Pluto might well be an effect of specular reflection; therefore, if the diameter obtained by Kuiper refers only to the central bright area and not of the whole disk, it may be that Pluto is much larger than has hitherto been supposed. It could not rank as a giant in the same way as Uranus or Neptune but it might well be considerably larger than the Earth itself. This would then explain why perturbations of these planets could take place.

There is another hypothesis of course, which is weakened by this new information and that is that Pluto may have been a satellite of Neptune which somehow was enabled to break free and move on an independent course.

Until recently the rotation period of Mercury has been given as 88 days and it has always been supposed that it makes one revolution on its own axis during its orbital period in the same way that the Moon does, turning always the same face to the Sun. Doubt has now been thrown on this by measurements made by the 1,000 ft radio telescope at Arecibo; and it is now suggested by Pettengill that the rotation period may well lie between 46 and 59 days, depending on whether its motion is forward or retrograde. Calculations made by Gold show that the period should be of the order of 59 days. Here then is another horizon which is opened as a result of the efforts of radio astronomers attacking preconceived notions of the planets.

The same radio observatory was of course, responsible for the statement to which it adheres that Venus has in fact retrograde

motion of the order of 240–50 days. It would appear then that the solar system still offers very much of an open field for those workers who are prepared to re-examine old ideas.

Finally, we must come to the newest and most exciting discovery of all: that is quasars or quasi-stellar objects. A year ago there were only a handful of them known, now they are thought to be quite numerous and extensive and new techniques have already been developed for their detection. There has been so much written on quasars both in the popular press and in the scientific journals that it would be superfluous to go through the details again. But at the moment they raise some of the most exciting problems regarding the Universe.

First, when the quasars were discovered it seemed that this would assist the steady-state theory of cosmology, now they are becoming so numerous that they are supporting the idea of an exploding Universe rather than that of the steady-state. The most recent method of detection has been devised by the team at Cambridge under Professor Ryle and Dr Hewish. When the energy from radio sources is received by a radio telescope in most cases the radiation is reasonably steady over a period. Until recently only one source was known to vary to any extent and this was found to be decreasing in energy year by year. However, in the case of quasars, most of them are so remote that the interplanetary medium is sufficient to make them twinkle in the same way that the normal atmospheric scintillation appears in respect of ordinary starlight. There seem to be interplanetary clouds made up of plasma, that is large lumps of gas thrown off by the Sun, each of such a nature that they can obscure the small amount of radiation that reaches us from these far distant radio objects. These clouds travelling at speeds of the order of 500,000 miles an hour cause sufficient scintillation of the radiation for it to be detected by a radio telescope.

A number of quasars have been discovered by this method and the programme of work will continue. The results of this work could very well provide the basis for the solution of our present problems in cosmology.

PART THREE

For Stellar Observers

Despite the fact that most amateur work is concentrated upon observations of bodies in the Solar System, there is a great deal to be gained also from stellar studies – and in the field of variable star work, particularly, the amateur can make himself very useful indeed.

Various lists have been given in earlier *Yearbooks*, including a detailed description of some clusters and nebulæ in last year's edition. James Muirden has now treated some double and binary stars in the same way, and though his 'cycle' – like his last – makes no pretence of being exhaustive, it may well inspire some observers to take up double star study, and begin measuring the separations and position angles of binaries. The Greek alphabet, used in the maps, is as follows:

α Alpha	ϵ Epsilon	ι Iota	ν Nu	ρ Rho	ϕ Phi
β Beta	ζ Zeta	κ Kappa	ξ Xi	σ Sigma	χ Chi
γ Gamma	η Eta	λ Lambda	o Omicron	τ Tau	ψ Psi
δ Delta	θ Theta	μ Mu	π Pi	υ Upsilon	ω Omega

Since there is also a good deal to be gained from comparing the colours of different stars, some notes are given here about stars of the first magnitude; and there are lists of selected nebular objects and telescopic variables.

The First-Magnitude Stars

By convention, a 'first-magnitude star' is taken to be any star of magnitude 1·4 or brighter. The list therefore ends with Regulus (1·36); Adara in Canis Major and Castor in Gemini just fail to meet the qualification. There are thus 21 first-magnitude stars, of which Canopus in Argo Navis, Achernar in Eridanus, Alpha and Beta Centauri, and Alpha and Beta Crucis are too far south to be seen in Europe or most of the United States. Apart from the erratic southern Eta Argûs (or Eta Carinæ), which has been below naked-eye visibility now for eighty years or so, no ordinary variable ever attains the first magnitude – apart from Betelgeux in Orion, which never fades below 1·2, and so is a permanent member of the clan.

There is much to be learned from looking at the first-magnitude stars with binoculars or a small telescope, because their different hues show up well. This is not the case with fainter stars, unless a moderate power be used. For instance, Arcturus in Boötes and Kocab, or Beta Ursæ Minoris, are of the same spectral type (K), but whereas the colour of Arcturus is striking at a glance, that of Kocab is not – simply because the intensity of its light is much lower.

The following notes on first-magnitude stars may, therefore, be of interest. It should be borne in mind that some of the values given for luminosities and distances are the reverse of certain; for example, the candle-power of Rigel, in terms of that of the Sun, is given variously as between 18,000 and 50,000 and its distance as 540 to 900 light-years.

Sirus (Alpha Canis Majoris). Magnitude −1·43, and much the brightest of the stars, its only rival being the southern Canopus (−0·73). Sirius cannot be mistaken, as it lies in line with the three

stars of Orion's belt, and in any case its brilliance makes it stand out at once. It is of spectrum A1, so that its colour is white, but atmospheric effects make it seem to flash with red, blue and green, particularly when it is very low down. It is, of course, a winter object. Sirius is one of our nearest neighbours in space; it is 8½ light-years away, and is 26 times as luminous as the Sun. It has a small White Dwarf companion, described in James Muirden's article.

Arcturus (Alpha Boötis). Though not circumpolar in Britain or the United States, Arcturus lies well north of the celestial equator, and remains prominent for a large part of the year. Its magnitude is −0·06; it is easily located, since it follows the continuation of the curve making up the tail of the Great Bear (or the handle of the Plough). Arcturus has a K2-type spectrum, and is a lovely light orange; binoculars bring this out splendidly. It is 100 times as luminous as the Sun, and is 41 light-years away. Apart from Sirius, it is the only star visible from Europe which is above zero magnitude, though there is very little difference between Arcturus, Vega, Capella and Rigel.

Vega (Alpha Lyræ). Magnitude 0·04. During summer evenings Vega lies almost overhead, and cannot be mistaken, partly because it is so bright and partly because of its glorious blue colour. Its spectrum is A0, and it is the equal of 50 Suns; it lies at a distance of 26 light-years. Vega was one of the first three stars to have its distance measured (the other two being Alpha Centauri and 61 Cygni), though admittedly the first estimates were considerably too small. Vega is the only really brilliant star of true bluish cast, and is always worth looking at. It is an optical double; the companion is some distance away, and is rather faint.

Capella (Alpha Aurigæ). Magnitude 0·05, so that it is to all intents and purposes equal to Vega. It is a very close binary, separable only with the very largest telescopes. The spectrum is of solar type (G), so that the surface temperature is about the same as that of the Sun; Capella is, however, 150 times as luminous,

and is 47 light-years away. The colour is a beautiful yellow. Just as Vega is overhead during summer evenings, so Capella occupies the zenith during winter evenings; in fact Capella, Polaris and Vega are in almost a straight line, with Polaris in the middle. Like Vega, Capella is just circumpolar in England, but not from New York, where it dips below the horizon. One certain way to identify Capella is to note the triangle of three fainter stars beside it. Two of these stars, Epsilon and Zeta Aurigæ, are remote eclipsing binaries of exceptional interest to astrophysicists; the fainter component of Epsilon Aurigæ is actually the largest star known.

Rigel (Beta Orionis). Rigel is very slightly variable, but may be taken as 0·1, almost equal to Capella and Vega. It is the leader of Orion, and is very luminous – perhaps equal to 50,000 Suns, in which case it must be some 900 light-years away. It has a B8-type spectrum and a very high surface temperature. In colour it is practically pure white, but from Europe and much of the United States it is never seen to maximum advantage, since it lies well south of the celestial equator.

Procyon (Alpha Canis Minoris). Magnitude 0·37. Procyon is 'only' 5 times as luminous as the Sun, and so is the feeblest of the first-magnitude stars apart from the southern Alpha Centauri. It is 10 light-years off. Procyon may be found in the Orion region, but rises high over Europe, since it lies slightly north of the celestial equator. The spectrum is F5, and the colour yellowish, though the departure from white is not marked. It has a faint companion which may be a White Dwarf.

Betelgeux (Alpha Orionis). This is one of the most interesting of all the bright stars. It is a Red Giant of spectrum M2, and it is some 250,000,000 million miles in diameter – large enough to hold the entire orbit of the Earth round the Sun. The diameter varies somewhat, since Betelgeux is not an ordinary stable star. Like many Red Giants, it is variable, though the magnitude range is relatively modest. Opinions differ, but it seems that it may rise to as much as 0·1, and drop to as little as 1·2, so that it may either

equal Rigel or become inferior to Aldebaran. There is a very rough period of about 5 years, according to some authorities. With any optical aid, the orange-red hue of Betelgeux is really striking. Its distance is given as 190 light-years and its luminosity 1,200 times that of the Sun, so that it is much closer than any of the other leading stars in Orion; in fact, Rigel is much further away from Betelgeux than we are.

Altair (Alpha Aquilæ). Magnitude 0·80; spectrum A7, so that the colour is white. Altair is relatively near, as it is only 16 light-years away; of the first-magnitude stars, only Sirius, Procyon and Alpha Centauri are closer. Altair is a summer object, rising high above the European horizon; it has a fainter star to either side (Gamma and Beta Aquilæ) a characteristic shared only by Antares. With Vega and Deneb, it makes up the famous Summer Triangle which dominates the night sky for several months in each year.

Aldebaran (Alpha Tauri). Magnitude 0·85, though very slightly variable. Like Betelgeux, Aldebaran is orange-red in hue, so that it makes a good comparison for Betelgeux; generally Betelgeux is rather the brighter of the two. Aldebaran has a K5-spectrum, and is 57 light-years away, while it is the equal of 90 Suns. It is extremely large, though not to be compared with true supergiants such as Betelgeux and Antares. Though it is apparently contained in the Hyades cluster, it is not a true member; it simply happens to lie in the same direction as seen from Earth, and the Hyades are twice as remote from us.

Antares (Alpha Scorpionis). Magnitude 0·98 (very slightly variable). The name 'Antares' means 'the Rival of Ares' (Mars), and certainly Antares is the reddest of the bright stars. Seen through a telescope, it looks almost like a glowing coal. The beauty is enhanced if the instrument used is powerful enough to show the 7th-magnitude green companion. Antares, with a diameter of some 300,000,000 miles, is even vaster than Betelgeux, and is 3,400 times brighter than the Sun; its distance is 360 light-years. Unfortunately it lies well south of the celestial equator, and

never rises high in Britain or the northern States, but its colour makes it stand out, and – like Altair – it has a fainter star to either side, in this case Tau and Sigma Scorpionis.

Spica (Alpha Virginis). Magnitude 1·00. Spica is prominent in the spring and early summer; it may be found by continuing the line from the Great Bear's tail through Arcturus. Though Spica is in the south part of the sky, it rises to a tolerable altitude over Britain and the whole of the U.S.A. It is very luminous (1,500 Sun-power) and lies at a distance of about 230 light-years. The spectrum is B1, so that Spica is virtually pure white.

Fomalhaut (Alpha Piscis Austrini). Magnitude 1·16. Fomalhaut is the southernmost of the first-magnitude stars visible from Britain; it may become quite prominent from South England, but from North Scotland it scarcely rises at all. From states such as Arizona and California it may be seen to advantage. There should be no difficulty in identifying it, because two of the stars in the Square of Pegasus (Beta and Alpha Pegasi) point downward toward it. Fomalhaut is best seen during autumn evenings; it is of spectrum A3, and is white, with a luminosity of 13 times that of the Sun and a distance of 24 light-years. During 1966, the only bright object anywhere near it will be the planet Saturn, which is rather more brilliant, well to the west, and much higher up.

Pollux (Beta Geminorum). Magnitude 1·16. Pollux is the brighter of the Twins, and is appreciably superior to Castor, its neighbour. If the astronomers of Classical and Arab times are to be trusted, the reverse used to be the case, with Castor of the first magnitude and Pollux only of the second, but it is perhaps unwise to place too much reliance on the old estimates. At the present time, the difference between the two is very obvious indeed. In colour, too, they differ; Castor is white, while Pollux (spectrum K0) is yellowish-orange. It is instructive to take a small telescope and look at the two Twins in turn. Pollux is 32 light-years away, and 28 times as luminous as the Sun. Since the Twins are in the northern hemisphere of the sky, they are well seen from Europe

over long periods of the year; Orion lies not far off, and Rigel and Betelgeux act as rough pointers to the Twins.

Deneb (Alpha Cygni). Magnitude 1·26. Though only 19th in order of apparent magnitude, Deneb is actually more luminous than any of the first-magnitude stars apart from Canopus and Rigel. It is at least 10,000 times as powerful as the Sun, and even this may be an under-estimate if its distance proves to be more than the official 650 light-years. With Vega and Altair, it makes up the Summer Triangle; it is also a member of the Cross of Cygnus. Its spectrum is peculiar, but similar to type A, so that the colour is white. Deneb is an unusual star in many respects, and has been closely studied by astrophysicists.

Regulus (Alpha Leonis). Magnitude 1·36, so that Regulus is the faintest of the first-magnitude stars. It is the leader of Leo, and may be found by using Dubhe and Merak, the 'Pointers', in the direction opposite to that for locating Polaris. The spectrum is B7, but the star is to all intents and purposes white. It is 70 times as luminous as the Sun, and 56 light-years away. Classical astronomers ranked it as inferior to Beta Leonis, or Denebola, but Denebola is now below the second magnitude, and cannot be compared with Regulus; it may genuinely have faded, though we cannot be sure. Regulus is a prominent feature of the night sky in spring and early summer. During 1965, the planet Mars lay not far from it, and for a time considerably outshone it.

The first-magnitude stars too far south to be seen from the latitude of Europe or New York are:

Canopus (Alpha Argûs or Alpha Carinæ). Magnitude −0·73. Spectrum F0. Luminosity given as 80,000 times that of the Sun, though authorities do not agree well. Distance, adopting this candle-power, over 650 light-years. Yellow.

Alpha Centauri. A binary; combined magnitude −0·27. Spectrum of the brighter component, G2; distance 4 light-years; luminosity 1·1 Sun-power. Yellowish.

Achernar (Alpha Eridani). Magnitude 0·53. Spectrum B5; luminosity 200 Sun-power; distance 66 light-years. White, perhaps with a bluish tinge.

Agena (Beta Centauri). Magnitude 0·66; distance 300 light-years; luminosity 3,000 times that of the Sun; spectrum B0; slightly bluish in colour.

Acrux (Alpha Crucis). Magnitude 0·87; distance 230 light-years; luminosity 1,000 times that of the Sun; spectrum B0. These statistics apply to the brighter component, since Acrux is a fine binary.

Beta Crucis. Magnitude 1·31, thus just ranking as of the first magnitude. Distance 200 light-years; luminosity 850 times that of the Sun; spectrum B0, so that the colour is bluish. Like Acrux, Beta Crucis is contained in the Southern Cross. Gamma Crucis, also in the Cross, is a reddish giant, of magnitude 1·6 and therefore not reckoned as in the senior group, though it is only one-third of a magnitude fainter than Beta Crucis.

It is interesting to compare the apparent magnitudes of the brightest stars with the values which these magnitudes would have if the stars were all at the same distance from us. The list would look very different, with Sirius almost at the bottom instead of at the top!

First-Magnitude Stars in Order of Apparent Brilliancy	*The Same Stars in Order of Actual Luminosity*
1. Sirius	1. Canopus
2. Canopus	2. Rigel
3. Alpha Centauri	3. Deneb
4. Arcturus	4. Antares
5. Vega	5. Agena
6. Capella	6. Spica
7. Rigel	7. Betelgeux
8. Procyon	8. Acrux
9. Achernar	9. Beta Crucis
10. Betelgeux (var.)	10. Achernar

11. Agena	11. Capella
12. Altair	12. Arcturus
13. Aldebaran	13. Aldebaran
14. Acrux	14. Regulus
15. Antares	15. Vega
16. Spica	16. Pollux
17. Fomalhaut	17. Sirius
18. Pollux	18. Fomalhaut
19. Deneb	19. Altair
20. Beta Crucis	20. Procyon
21. Regulus	21. Alpha Centauri

Some Interesting Variables for Telescopic Observation

Star	R.A.		Dec.		Magnitude				
	h	*m*	°	′	*max*	*min*	*Period, d.*	*Spec.*	*Type*
T Ceti	00	19	—20	20	5·1	7·0	—	M	Irregular
R Andromedæ	00	21	+38	18	5·6	15	410	M	Long-period
R Sculptoris	01	25	—32	49	6·2	8·8	376	N	Long-period
Omicron Ceti	02	17	—03	12	1½	9·6	331	M	Long-period
R Trianguli	02	34	+34	03	5·8	12	270	M	Long-period
R Leporis	04	57	—14	53	6·0	10·5	430	N	Long-period
U Orionis	05	53	+20	11	5·4	12	374	M	Long-period
RT Aurigæ	06	25	+30	33	5·0	6·0	3·7	G	Cepheid
R Geminorum	07	04	+22	48	5·9	14	370	M	Long-period
R Cancri	08	14	+11	53	6·0	11	362	M	Long-period
R Leo. Minoris	09	43	+34	45	6·2	12	370	M	Long-period
R Leonis	09	45	+11	40	4·9	10·5	312	M	Long-period
U Hydræ	10	35	—13	07	4·5	6·0	—	N	Irregular
T Ursæ Majoris	12	34	+59	46	5·5	13	254	M	Long-period
R Virginis	12	36	+07	16	6·0	12	145	M	Long-period
R Hydræ	13	27	—23	01	4·0	10·1	415	M	Long-period
S Virginis	13	30	—06	56	5·6	12·3	372	M	Long-period
W Hydræ	13	46	—28	07	6·5	7·9	383	M	Long-period
R Boötis	14	35	+26	52	6·0	13	222	M	Long-period
W Boötis	14	41	+26	44	5·2	6·2	—	K	Irregular
Delta Libræ	14	58	—08	19	4·8	6·2	2·3	A	Algol type
S Coronæ Bor.	15	19	+31	33	6·1	12	360	M	Long-period
R Coronæ Bor.	15	46	+28	19	5·8	12·5	—	Pec.	Irregular
T Coronæ Bor.	15	57	+26	04	1·9	9·5	—	Pec.	Recurrent nova
S Herculis	16	50	+15	02	5·9	12·5	300	M	Long-period
u Herculis	17	16	+33	09	4·8	5·4	2·1	B	Beta Lyræ type
R Scuti	18	45	—05	46	4·7	7·7	—	G	Irregular
R Lyræ	18	54	+43	53	4·0	4·8	—	M	Irregular
R Aquilæ	19	04	+08	09	5·8	12	309	M	Long-period
Chi Cygni	19	49	+32	48	4·2	13·7	409	M	Long-period
T Vulpeculæ	20	49	+28	03	5·2	6·4	4·4	F	Cepheid
Mu Cephei	21	42	+58	33	3·6	5·6	—	M	Irregular
R Pegasi	23	06	+10	02	5·5	7·5	—	M	Irregular

Some Interesting Clusters and Nebulæ

Object	R.A. h	m	Dec. °	′	*Remarks*
M.31 Andromedæ	00	40·7	+41	05	Great Galaxy, visible to naked eye.
H.VIII 78 Cassiopeiæ	00	41·3	+61	36	Fine cluster, between Gamma and Kappa Cassiopeiæ.
M.33 Trianguli	01	31·8	+30	28	Spiral. Difficult with small apertures.
H.VI 33–4 Persei	02	18·3	+56	59	Double cluster; Sword-handle.
M.1 Tauri	05	32·3	+22	00	Crab Nebula, near Zeta Tauri.
M.42 Orionis	05	33·4	—05	24	Great Nebula. Contains the famous Trapezium, Theta Orionis.
M.35 Geminorum	06	06·5	+24	21	Open cluster near Eta Geminorum.
H.VII 2 Monocerotis	06	30·7	+04	53	Open cluster, just visible to naked eye.
M.41 Canis Majoris	06	45·5	—20	42	Open cluster, just visible to naked eye.
M.44 Cancri	08	38	+20	07	Præsepe. Open cluster near Delta Cancri. Visible to naked eye.
M.97 Ursæ Majoris	11	12·6	+55	13	Owl Nebula, diameter 3′. Planetary.
M.3 Canum Venaticorum	13	40·6	+28	34	Bright globular.
M.80 Scorpionis	16	14·9	—22	53	Globular, between Antares and Beta Scorpionis.
M.4 Scorpionis	16	21·5	—26	26	Open cluster close to Antares.
M.13 Herculis	16	40	+36	31	Globular. Just visible to naked eye.
M.92 Herculis	17	16·1	+43	11	Globular. Between Iota and Eta Herculis.
M.7 Scorpionis	17	51·6	—34	48	Fine open cluster. Very low in England.
M.23 Sagittarii	17	54·8	—19	01	Open cluster nearly 50′ in diameter.
H.VI 37 Draconis	17	58·6	+66	38	Bright planetary.
M.8 Sagittarii	18	01·4	—24	23	Lagoon Nebula. Gaseous. Just visible with naked eye.
NGC 6572 Ophiuchi	18	10·9	+06	50	Bright planetary, between Beta Ophiuchi and Zeta Aquilæ.
M.17 Sagittarii	18	18·8	—16	12	Omega Nebula. Gaseous. Large and bright.
M.11 Scuti	18	49·0	—06	19	Wild Duck. Bright open cluster.
M.57 Lyræ	18	52·6	+32	59	Ring Nebula. Brightest of planetaries.
M.27 Vulpeculæ	19	58·1	+22	37	Dumb-bell Nebula, near Gamma Sagittæ
H.IV 1 Aquarii	21	02·1	—11	31	Bright planetary near Nu Aquarii.
M.15 Pegasi	21	28·3	+12	01	Bright globular, near Epsilon Pegasi.
M.39 Cygni	21	31·0	+48	17	Open cluster between Deneb and Alpha Lacertæ. Well seen with low powers.

A Cycle of Double Stars

JAMES MUIRDEN

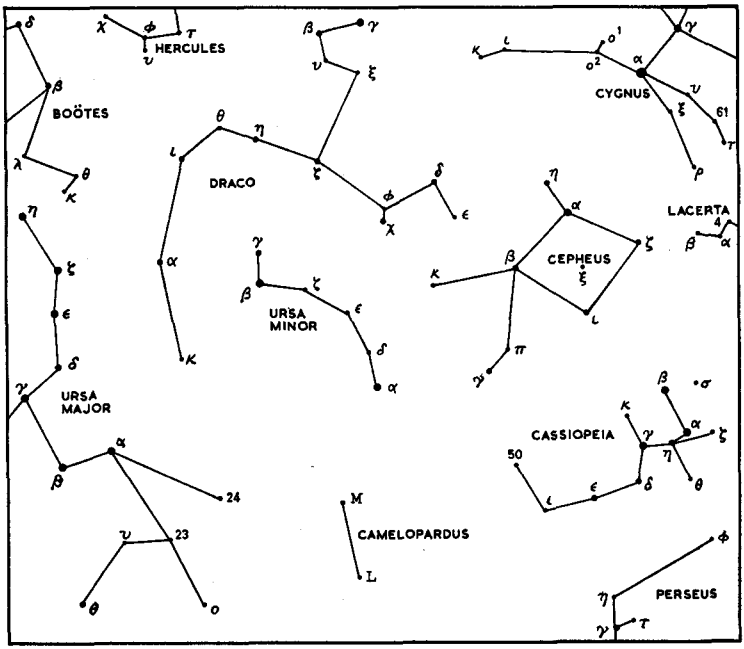
In the 1965 *Yearbook* I described a brief tour of some of the better-known nebulæ and clusters that decorate our night skies. This year I am glad to have the opportunity of repeating the survey, now concentrating on those perplexing and often beautiful objects known as double stars. J. C. Vetterlein described their nature in the 1962 *Yearbook*, and I shall here deal simply with their appearance in the sort of small telescope (3-inch refractor or 6-inch reflector) that the amateur is likely to possess. After each pair are given the magnitudes of the components, the distance between them in seconds of arc, and the position angle of the fainter star relative to the brighter.

The seasonal treatment is a convenient way of covering the sky, and I shall repeat the method here.

SPRING

Let us begin with the most famous star in the sky: the Pole Star (Alpha Ursæ Minoris; Map I). This is a well-known double (2·1, 9·0; 18″; 217°), and is actually a fair test of atmospheric conditions, for although the companion is bright enough to be easily seen on its own, the presence of the Pole Star itself obscures it in the general glare. A clear view of the companion with a small telescope indicates a night that should be used to profit on better objects.

Ursa Major, the Little Bear's companion (Map I), possesses a famous and very attractive double in Zeta (*Mizar*), the star at the bend of the 'handle'. A clear-sighted person will see a fainter star, *Alcor*, very close to *Mizar*; turn a telescope on to this pair and the faint star jumps into prominence; moreover, *Mizar* itself proves to

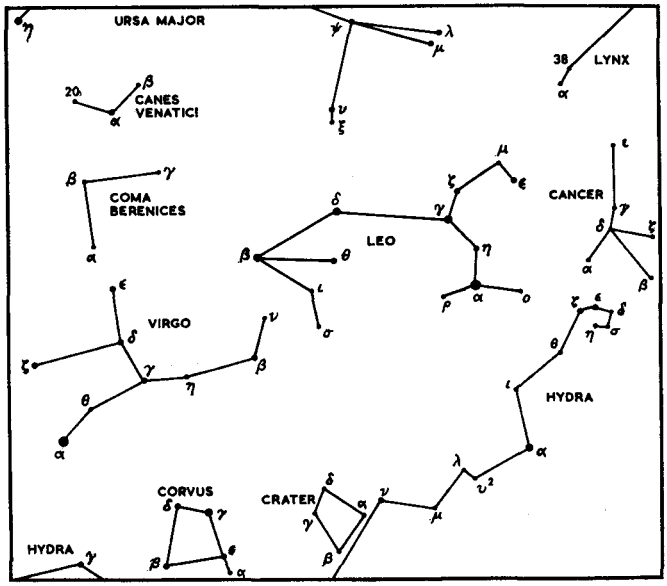


Map I

be a fine double (2·4, 4·2; 14″·5; 150°). There is a greenish or greyish hue in the pair that I find difficult to define. Another pretty double is 23, lying on a line projected from Epsilon through Alpha (3·8, 9·0; 23″; 271°); the primary has a yellowish tint, while the companion is bluish.

Canes Venatici (Map II) is obscure to the naked eye, but Alpha (*Cor Caroli*) is well worth looking at (3·2, 5·7; 20″; 228°), the stars both being yellow. The nearby constellation of Boötes (Maps I and III), however, is much more prominent, and it contains a number of fine pairs. The most famous is Epsilon (3·0, 6·3; 2″·8; 340°), which the great double-star observer Struve regarded as the most beautiful pair in the sky. It is rather close for a 3-inch, but careful gazing with a high power will show the fine

contrast between the yellow primary and its light green companion. Two other attractive doubles are Kappa (5·1, 7·2; 13″; 237°), and Pi (4·9, 6·0; 6″; 200°).



Map II

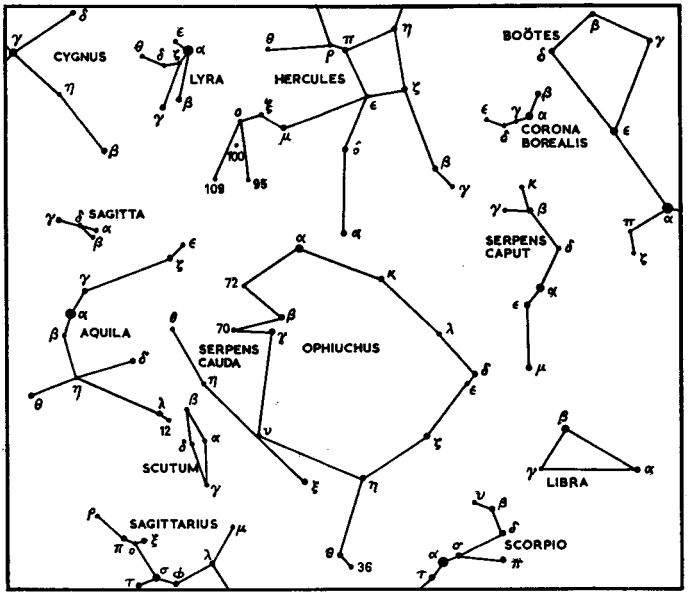
Leo and Virgo (Map II) each possess a fine pair in their respective Gammas. Gamma Leonis (2·6, 3·8; 4″·3; 121°) shines with a rich bronze tint; it is a true binary, with a period of about 400 years. Gamma Virginis is even finer (3·6, 3·7; 4″·8; 305°), with the yellow components almost exactly matched. This too is a binary, with a period of 180 years, and by the end of the century the stars will have moved so close together that only the largest telescopes will be able to separate them. Anyone wanting to test their sky conditions would do well to tackle Theta (4·0, 9·0; 7″; 340°), which at the time of writing is in the same region as the planet Uranus.

SUMMER

Vega (Alpha Lyræ; Map III) is the brightest star in the summer sky, and it is also a double (0·0, 10·5; 60″; 180°); but anyone glimpsing the minute companion with less than a 4-inch refractor can justly praise both himself and the local atmospheric conditions. Lyra and Cygnus are both in such a rich part of the Milky Way that doubles can be swept up at random; but mention should certainly be made of Epsilon Lyræ, the famous 'double-double'. Very keen eyes, or at best an opera glass, will show the star Epsilon (forming a little triangle with *Vega* and Zeta) to be double. A small telescope then resolves each component into a close double (4·6, 6·3; 3″; 5° and 4·9, 5·2; 2″·3; 111°). The constellation also contains a miniature of this feature in the pairs Σ2470 and Σ2474 (the Greek letter Σ signifies Struve's catalogue). These pairs, although both below the sixth magnitude, are easily swept up just south of the line joining Theta and Gamma Lyræ, and form an attractive sight.

Cygnus (Maps III and IV) contains two famous pairs. Beta, the star forming the foot of the 'cross', is a beautiful sight (3·0, 5·3; 35″; 55°), with the gold and greenish blue of the components finely contrasted; it can in fact just be split with binoculars. Then there is 61 (the number in Flamsteed's catalogue of 1725), which in 1838 earned the distinction of being the first star to have its distance accurately measured. 61 Cygni forms a rough parallelogram with Alpha, Gamma and Epsilon, and its vital statistics are 5·3, 5·9; 25″; 150°, both stars being yellow.

Delphinus (Map IV) is a compact constellation south of Cygnus, and the star Gamma is a most beautiful sight (4·0, 5·0; 10″; 265°; yellow and green). On the other side of Lyra, in Hercules, there are a great many fine pairs, of which the leader, Alpha, is a good example (3·0, 6·1; 4″·5; 110°), the tints being yellow-gold and vivid green. Then there is a neat pair in Rho (4·0, 5·1; 4″; 320°), both grey, and also in 95 (4·9, 5·0; 6″; 260°). Most catalogues mark these stars as equal, but my eyes suggest that the yellow member is slightly brighter. 100 Herculis is rather



Map III

similar (5·9, 5·9; 14″; 183°) except that the stars are identical in all respects.

If we now look towards the overhead point we find the distinctive parallelogram of Cepheus (Map I), with the star Xi at its centre forming a very pretty object (4·7, 6·5; 8″; 270°). The primary is cream, the companion a curious rusty hue. Most of the other doubles in this constellation are rather faint, and it might be more worthwhile to turn to the inconspicuous group of Lacerta (Maps I and IV), whose star 8 consists of a neat pair (6·0, 6·5; 22″; 186°), with a 9th and 10th magnitude pair nearby forming an attractive group.

Ophiuchus (Map III), descending now towards the southern horizon, is an extensive but somewhat barren constellation. 36, rather low in the sky near Theta, is a pretty object (5.6, 5·7; 2″·5;

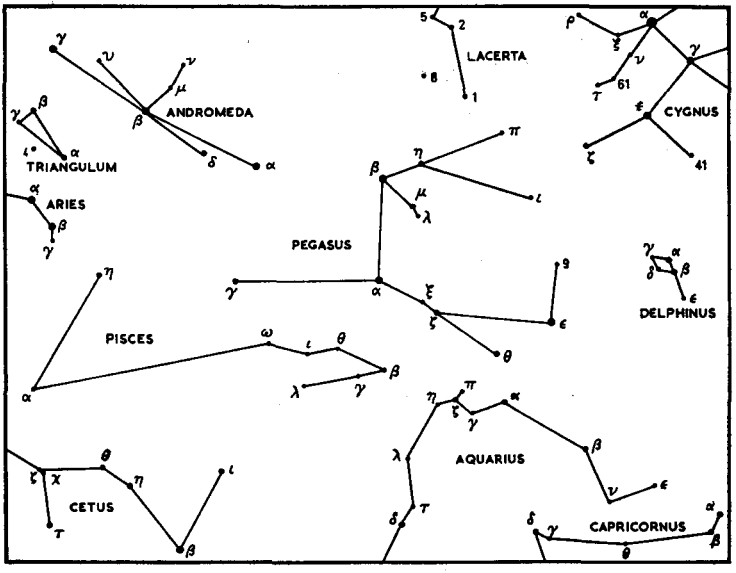
200°), both stars being yellow, while 70 is a glorious sight, shining with a golden tint. The catalogue gives it as 4·3, 6·0; 6″; 118°, but to my eyes there is only a magnitude difference, while the distance is more like 3″ and the PA is about 90°. The pair forms a binary system with a period of 88 years, and in such cases the quoted distances and position angles rapidly become of historical interest only!

To the east of Ophiuchus, in Serpens Cauda (Map III), lies a noble pair in a fine field. This is Theta (4·0, 4·2; 23″; 103°), both stars being white; and in the same region we find the fiery red star *Antares* (Alpha Scorpii), whose faint green companion is so difficult to see from high northern latitudes. The star's statistics (1·0, 6·8; 3″; 275°) state the problem clearly enough. Atmospheric turbulence normally loses the faint star in the primary's rays, and a night on which it can be clearly seen should be taken advantage of to the full.

AUTUMN

The shrinking days of autumn are characterised for the astronomer by the presence of the Great Square of Pegasus in the southern sky. Pegasus (Map IV) is itself of little interest, but the line of Andromeda (Map IV) leads off to the east, and the third star, Gamma, is an attractive double for the user of a small telescope (3·0, 5·0; 9″; 60°). The colours of gold and blue are more intense than in Beta Cygni, and show up very well indeed. The companion is itself a close double, but this is a sight reserved for moderate telescopes.

The prim constellation of Triangulum (Map IV) shelters beneath Andromeda's line, and Iota (5·0, 6·4; 4″; 70°) is worth a glance for its yellow and blue tints. South again is Aries (Maps IV and V), with the spectacular Gamma (4·2, 4·4; 8″; 360°), which is a pleasing sight in any instrument. Epsilon, which lies towards Taurus, is a good test-object for a small telescope; I have just divided it with a 3½-inch refractor, ×200 (6·0, 6·4; 1″·5; 210°). South again is the curious star Alpha Piscium (Map IV), whose components bask in an appropriate watery-green hue (4·3, 5·3;



Map IV

1″·9; 291°). The nearby Gamma Ceti (Map V) is also a little baffling (3·7, 6·2; 3″; 300°). The primary is yellowish, the companion a curious colour that the late F. M. Holborn described as 'dull orange' and W. F. Denning, the famous meteor observer, called 'olive green'. One gets used to these occasional discordances after a time, but to begin with it does seem a little doubtful whether the observers were actually looking at the same star!

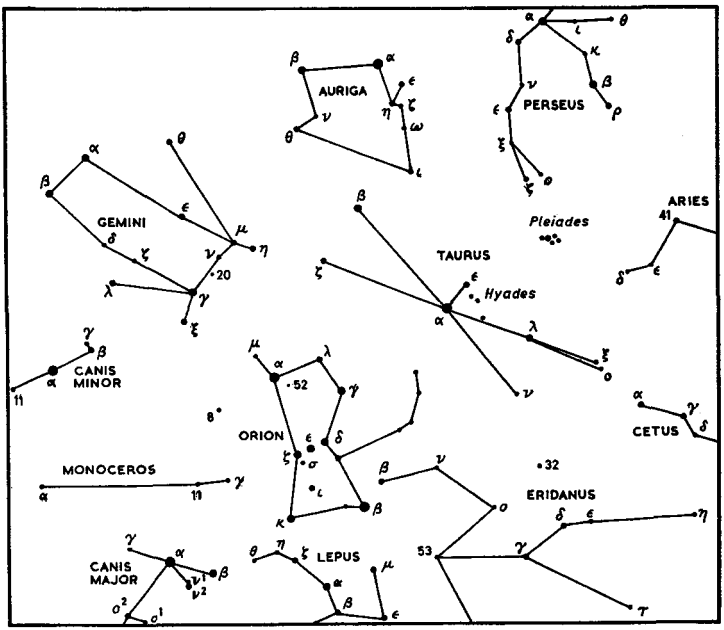
Taurus (Map V), with its distinctive groups of the Hyades and Pleiades, lies on the border of the autumn and winter classifications; and *Aldebaran*, its bright orange leader, certainly lies on the border of double star classification (0·8, 11·2; 130″; 32°). The minute distant companion is, at all events, a good test of sky clarity; under favourable conditions it should just be glimpsed by a keen eye with a 3-inch. Higher in the sky, the adjacent asterisms of Perseus (Maps I and V) and Cassiopeia (Map I) claim more attention. Here the Milky Way is magnificent, and random sweep-

ing will pick up many pairs, while Cassiopeia especially is richly endowed. The three finest are Eta (3·7, 7·4; 11″; 298°), with a cream primary and bluish companion and a string of faint stars following it in the field; Iota, consisting of three stars of magnitude 4·2, 7·1 and 8·1 in close association; and Sigma (5·4, 7·5; 3″; 330°), which lies in a magnificent field.

WINTER

Orion (Map V), at the core of the winter sky, contains a great many doubles that the amateur mentally associates with crisp nights and black skies. The most famous one is *Rigel*, Beta Orionis, which marks the Giant's right foot. The stars are 0·1, 6·7; 9″·5; 205°, and it is not at all a difficult object for a small telescope. Then there is Sigma, near the belt, a fine quartet of close stars of magnitude 4·0, 7·0, 7·5 and 10·0; Iota (3·2, 7·3; 11″; 140°), which lies south of the Great Nebula and actually carries one of its bright ramifications in the field; Theta itself – the famous Trapezium embedded in the nebula; and Zeta, a pretty pair (2·0, 5·0; 3″; 160°). Anyone seeking a severe test for a small telescope will find it in 52, which consists of two reddish 6th-magnitude stars at a distance of 1″·3. I have notched, but not divided it with a 3½-inch refractor; it is quite easily found, near Betelgeux.

Auriga (Map V), north of Orion, contains a couple of objects for the double-star collector. Omega, found on a line joining Iota and Zeta, is a delicate and pretty double (5·0, 8·0; 5″·2; 360°) with colours of white and blue; while Theta (2·7, 7·2, 3″; 330°) is one of the most subtle test-objects I have come across for my 3½-inch refractor; only on the very finest nights have I been able to make it out. Another good test, as well as being a splendid sight, is Alpha Geminorum (*Castor*) (Map V). The stars, of magnitude 2·0 and 2·8, form a long-period binary system; at the moment the distance is 1″·9; 151°, but it is increasing perceptibly each year, so that they will soon be very easy in a 3-inch. Another bright star in Gemini is a double: this is Delta (3·2, 8·2; 6″·5; 120°); while 20 Geminorum, near Gamma (6·0, 6·9; 20″; 211°) gives an attractive combination of yellow and blue.



Map V

East of Gemini, in the somewhat obscure asterism of Cancer (Map II), we find two very fine doubles. The first, Iota, is a wide yellow and blue combination (4·4, 6·5; 31″; 307°); this actually appears the second brightest star in the whole constellation, so Bayer's progressive designation, assigning Alpha to the leader of the group and descending in magnitude down the alphabet, has slipped up badly here. The other, Zeta, is a well-known test; it consists of an easy pair (5·6, 6·1; 5″·6; 82°), while the brighter star is a close double in itself (5·6, 5·9; 1″·1; 348°). I have managed to elongate the latter with my refractor, which is about all that one can expect. The three stars are yellowish.

We now sweep down towards the southern horizon and find one of the gems of the sky in Monoceros (Map V), to the east of

Orion. This is 11 Monocerotis, which is not too difficult to find since it lies in a rather barren patch of sky between Betelgeux and Sirius; the telescope reveals three stars of magnitude 5·0, 5·5 and 6·0 forming a most glorious triple. All three are white, and the two fainter stars, which are 3″ apart, are neatly divided with a low power; if I were asked to name one star to satisfy my requirements of beauty, I think it would be this one. 8 Monocerotis, on the border of Orion, is noteworthy for its field as well as being a neat pair (4·0, 6·7; 13″; 27°, yellow and blue). On the other side of Orion there is 32 Eridani (Map V); this is rather tricky to sweep up, but once located its fine tints of yellow and blue-green will more than repay the trouble (4·0, 6·0; 7″; 347°).

Canis Minor (Map V), a constellation distinguished by its yellow leader *Procyon*, contains a coarse triple, 14, that is worth looking up; it consists of 6th, 8th and 9th-magnitude stars. Its larger brother, Canis Major (Map V), offers a fine sight in Nu_1 (6·0, 6·8; 17″·5; 263°), with attractive contrast of yellow and violet; and it reserves, until the end of our cycle, one of the most elusive pairs in the sky. This is none other than the companion to Alpha (*Sirius*), which, although it is of the 7th magnitude, is so close to the glare of its primary (magnitude −1·44) that it is lost in all but the finest telescopes. The distance of the companion, which forms a true binary system, varies from 2″ to 11″·5 in a period of 50 years. The next widest separation is due in 1975; at the last one, F. M. Holborn saw it with his 8½-inch reflector, so that it will soon be time to face this recurrent challenge of the skies.

The stars mentioned here, which form but a tiny fraction of the wonderful pairs to be found from British latitudes, are all marked in *Norton's Star Atlas* as well as on the maps here, and can be easily found if the telescope is fitted with an efficient finder of at least 1½ inches aperture. I have spent countless hours of pleasure looking through the doubles cited in Webb's *Celestial Objects for Common Telescopes*: a treasure-house of celestial description that has recently been reprinted by Dover Publications (New York) and is now widely avaliable.

Britain's New Planetarium

PATRICK MOORE

During the past ten years or so, the planetarium has been gaining steadily in importance. At the end of the war, few planetaria existed; now they are becoming very common in schools and other educational establishments, and there are, of course, many large public installations in the United States, Europe and elsewhere. In Britain there has been only one: the Zeiss planetarium in London, sponsored by Madame Tussaud's, which has been in operation for some years.

In 1965 it was announced that another planetarium for public viewing is to be set up, this time at Armagh in Northern Ireland. Armagh, one of the oldest cities in Europe, is already the home of a major observatory, directed by Dr E. M. Lindsay, which has achieved much work of international importance, and which is actually the oldest observatory in Britain now operating in its original site (Greenwich Observatory having been completely removed to a new home at Herstmonceux, in Sussex). The Armagh Planetarium will be associated with the Observatory, and in the Observatory grounds, conveniently close to Armagh itself.

It is to be a non-commercial establishment, used solely for educational and scientific purposes, and financed jointly by the Ministry of Commerce and Development in the Northern Ireland Government, the Armagh City Council, and the Armagh County Council. The dome is to be 40 feet in diameter, and – a new approach in planetaria! – the seats are to be of the aircraft tip-back variety, so that the usual trouble of straining one's neck to peer up at the dome will be avoided. In every way the installation will be as up-to-date as any in the world, and there will also be an associated observatory, so that people who have been to a planetarium dis-

play will be able to carry out direct observations of the sky by the aid of a 12½-in. reflecting telescope (clouds, naturally, permitting), while in the daytime sunspots will be projected with a smaller refractor.

The projector is to be a Goto, made in Japan; the model is that of the 'Mars' type. There are various Goto installations in America, Australia and elsewhere, but this will be the first of its kind to be set up in Europe.

Beginners may well comment: 'If you can see the real sky, what is the purpose of setting up an artificial one?' Yet in fact, a planetarium is very much more than a mere projector to give a naked-eye view. As an aid to star recognition, for instance, it is invaluable, and a very few sessions will enable the complete novice to find his (or her) way around the constellations. Moreover, the whole sky, from pole to pole, will be covered by the Armagh projector, so that groups such as the Centaur, the Altar and the Southern Cross can be shown realistically. The movements of the planets can be shown and described, so as to make clear just how they behave, the rotation of the entire sky can be demonstrated, together with many other phenomena which are not easy to put into words but are easy to understand when 'shown in action', so to speak. And as an aid to navigational principles, the planetarium is unrivalled.

Great interest has already been shown in the new venture; the planetarium will, it is hoped, be used by audiences from abroad as well as from all over Ireland. Building is due to begin in the autumn of 1965; the projector is under construction in Japan, and, all being well, the installation will be opened some time in the late summer or early autumn of 1966.

PART FOUR

Miscellaneous

Astronomical Societies

The advantage of joining an astronomical socety are obvious enough. Full information about national and local Societies was given in the 1965 *Yearbook*; a condensed list, suitably brought up to date, is given below.

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
British Astronomical Association	303 Bath Road, Hounslow West, Middlesex (Miss Lydia A. Brown)	45*s* (§30*s*)	Burlington House, Piccadilly Last Wed. each month (Oct–June)
Junior Astronomical Society	44 Cedar Way, Basingstoke, Hampshire (E. W. Turner)	15*s*	Caxton Hall, London, S.W.1 Quarterly
Aylesbury Astronomical Society	9 Elm Close, Butler's Cross, Aylesbury (N. Neale)	20*s*	As arranged
Birmingham Astronomy Group	17 Hannafore Road, Edgbaston, (W. E. Marsh)	10*s* (§5*s*)	Birmingham and Midland Institute Monthly
Bristol Astronomical Society	12 Lambley Road, Bristol 5 (S. J. Williams)	20*s*	Lecture Theatre, Bristol University 3rd Friday each month, Sept–May
Caithness and Dounreay Astronomical Society	Room 31, Ormlie Lodge, Thurso, Scotland (Miss M. J. A. Clark)	20*s*	Fortnightly
Cambrian Astronomical Society	57 Park Avenue, Whitchurch, Cardiff (R. W. Skelly and W. H. Sutherland)	15*s* (§7*s* 6*d*)	Fortnightly, Friday evenings, Oct.–June, in Cardiff
Cambridge Astronomical Society	5 Haggis Gap, Fulbourn (S. R. Whistler)	21*s* (§7*s* 6*d*)	7 Brooklands Avenue, Cambridge 2nd Mon. each month, Oct.–July
Chester Society of Natural Science, Literature and Art	Grosvenor Museum, Chester	—	Grosvenor Museum, Chester Fortnightly
Chesterfield Astronomical Society	10 George Street, Brimington, Chesterfield (Mrs M. E. Garrod)	15*s*	Barnett Observatory, Newbold Each Friday
Crawley Astronomical Society	Crawley College of Further Education, Sussex (F. D. Cooper)	7*s* 6*d*	Crawley College of Further Education Monthly
Crayford Manor House Astronomical Society	Manor House Centre, Crayford, Kent (R. H. Chambers)	None	Manor House Centre, Crayford Monthly during term-time
Dundee Astronomical Society	4 Finlaggan Place, Dundee Scotland (D. Gavine)	10*s* (§5*s*)	Mill's Observatory, Dundee Fortnightly in the winter

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
Eastbourne Astronomical Society	80 Ringwood Road, Eastbourne, Sussex (W. O. Tutt)	21*s* (§10*s* 6*d*)	As arranged Monthly
Astronomical Society of Edinburgh	126 W. Saville Terrace, Edinburgh 9, Scotland (N. G. Matthew)	20*s*	Calton Hill Observatory, Edinburgh Monthly
Fellowship of Junior Astronomers, Edinburgh	58 Ogilvie Terrace, Edinburgh 11, Scotland (Miss Edith McLean)	7*s* 6*d*	Calton Hill Observatory, Edinburgh 2nd Sat. each month, Sept.–June
Astronomical Society of Glasgow	164 Mugdock Road, Milngavie, Glasgow, Scotland (N. M. Orr)	10*s*	Roy. Coll. Science and Tech., Glasgow 3rd Thur. each month, Sept.–April
Leeds Astronomical Society	Maths. Dept., The University, Leeds 2 (B. L. Meek)	10*s* (§5*s*)	Leeds University Six annually
Leicester Astronomical Society	49 Bringhurst Road, Leicester (C. Shuttlewood)	21*s* (§7*s* 6*d*)	Leicester Museum and Art Gallery Monthly
Lincoln Astronomical Society	344 Brant Road, Lincoln (P. Hammerton)	20*s* (§5*s*)	Lincoln YMCA Hall 1st Tue. each month
Liverpool Astronomical Society	135 St Michael's Road, Great Crosby, Liverpool 23 (J. E. Abrahams)	15*s* (§5*s*)	Royal Institution, Liverpool Monthly
Maidenhead Astronomy Group	129 Fane Way, Maidenhead, Berkshire (S. A. H. Roper)	10*s* (§2*s* 6*d*)	Maidenhead Grammar School Once every 3 weeks
Manchester Astronomical Society	Cragside, Cliff Avenue, Summerseat, Bury (Alan Whittaker)	20*s* (§10*s*)	Godlee Observatory, Manchester 1 Weekly
Newcastle-on-Tyne Astronomical Society	30 Kew Gardens, Whitley Bay, Northumberland (G. E. Manville)	20*s*	Botany Lecture Theatre, Newcastle University Monthly, Sept.–April
Oxshott Astronomical Group	Norman Cottage, Pond Piece, Sheath Lane, Oxshott, Surrey (E. H. Noon)	10*s*	Oxshott Village Centre 1st Wed. each month, Sept.–May
Plymouth Astronomical Society	127 Crownhill Road, Crownhill, Plymouth (Lawrence Harris)		(In the process of organization)
Preston and District Astronomical Society	51 Bispham Road, Carleton, Poulton-le-Fylde, Lancs (C. Lynch)	20*s* (§5*s*)	Chamber of Commerce, 49a Fishergate, Preston 3rd Mon. each month, Sept.–May
Salisbury Plain Astronomical Society	St George's Cottage Orcheston Salisbury, Wilts. (R. J. D. Nias)	10*s* (§5*s*)	St George's Rectory, Orcheston Quarterly
Sidereal Society	Flat 2, 11 Wellington Road, Brighton, Sussex (Mrs M. L. Cohen)	20*s* (§10*s*)	6 Brunswick Terrace, Hove, Sussex Each Wed., 7.30–9.30
Slough Astronomical Society	The Elms, Odds Farm, Green Common Lane, Wooburn Common, High Wycombe, Bucks (E. Shilton)	20*s*	Monthly

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
Southampton Astronomical Society	13 Luccombe Place, Shirley, Southampton (F. G. H. Cunningham)	20*s* (§10*s*)	Polygon Hotel, Southampton 2nd Thur. each month, Sept.–May
Stoke-on-Trent Astronomical Society	19 Engelsea Avenue, Weston Coyney, Stoke (T. F. Stringer)	20*s*	Hanley, near Stoke-on-Trent Monthly
Swansea Astronomical Society	77 Craiglwyd Road, Cockett, Swansea (R. E. Roberts)	20*s*	As arranged
Torbay Astronomical Society	4 Heath Rise, Brixham, Devon (Miss A. Longman)	15*s* (§5*s*)	Quay Tor Hotel, Scarborough Road, Torquay Monthly
Warwickshire Astronomical Society	20 Humber Road, Coventry, Warwickshire (R. D. Wood)	80*s*	20 Humber Road, Coventry Each Tuesday
Wolverhampton Astronomical Society	Garwick, 8 Holme Mill, Fordhouses, Wolverhampton (M. Astley)	20*s*	38 Tettenhall Road, Wolverhampton Alternate Mon., Sept.–April
York Astronomical Society	97 Carr Lane, Acomb, York (R. Emmerson)	20*s* (§5*s*)	As arranged Monthly, Sept.–May

It is possible that this list of local societies may not be quite complete. If any have been omitted, the secretaries concerned are invited to write to the Editor (c/o Eyre & Spottiswoode (Publishers), Ltd, 167 Fleet Street, London EC4), so that the relevant notes may be included in the 1967 *Yearbook*.

Some Recent Books

The Planet Uranus, by A. F. O'D. Alexander. (Faber & Faber, London, 1965.) A full, scholarly study of this remote planet, treated from every aspect, and certain to become the standard reference work.

Exploring the Planets, by V. A. Firsoff. (Sidgwick & Jackson, London, 1964.) An interesting account, containing several new theories due to the author.

Life on Mars, by F. L. Jackson and P. Moore. (Routledge & Kegan Paul, London, 1965.) A semi-technical study, written jointly by a microbiologist and an astronomer.

Space Physics, by H. S. W. Massey. (Cambridge University Press, 1964.) A clearly-written technical book, invaluable to the serious student.

The Sky at Night, by Patrick Moore. (Eyre & Spottiswoode, London, 1964.) A series of articles based on the monthly television programme of the same title.

Norton's Star Atlas, Gall & Inglis. (Edinburgh, 1964.) The long-awaited new edition of this classic work, invaluable to the amateur observer and valuable also to the professional. It has been revised and skilfully brought up to date by N. G. Matthew.

Optical Astronomy, by C. A. Ronan. (Phoenix House, London, 1964.) An account of recent developments in techniques of optical astronomy, with considerable background information also.

Yearbook of Astronomy 1966

Editor Patrick Moore

This yearbook has been specially designed for the amateur astronomer and, once again, the new edition has been completely revised. The notes and data have been brought up to date for 1966 and a new series of articles included.

These deal with subjects ranging from the edgewise presentation of Saturn's rings to the construction of Cassegrain reflectors and telescopic drives, as well as Patrick Moore's usual article on recent advances in astronomy. There are also details of the first-magnitude stars, of variables and nebulae suitable for telescopic observation and a cycle of double stars, which is included for the first time in this edition. A full list of societies that the amateur astronomer can join together with details of their meetings is also given.

The *Yearbook* is of great value to all interested in astronomy and particularly to the amateur who likes to look out for the planets and other astronomical events.

The illustration on the front of the jacket is from an East German photograph of Solar Prominences taken on 28 January 1958. At this time the Sun was highly active. Minimum was reached during 1964, and activity is now starting to rise again toward the next maximum.

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167 Fleet Street London EC4